



INDO-PACIFIC BOTTLENOSE DOLPHIN ASSESSMENT WORKSHOP REPORT

Solomon Islands case study of *Tursiops aduncus*

Edited by R.R. Reeves and R.L. Brownell Jr.



Occasional Paper of the IUCN Species Survival Commission No. 40

INDO-PACIFIC BOTTLENOSE DOLPHIN ASSESSMENT WORKSHOP REPORT

Solomon Islands case study of *Tursiops aduncus*

Edited by R.R. Reeves and R.L. Brownell Jr.



The designation of geographical entities in this book, and the presentation of the material, do not imply the expression of any opinion whatsoever on the part of IUCN or other participating organizations concerning the legal status of any country, territory, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The views expressed in this publication do not necessarily reflect those of IUCN.

Published by: IUCN, Gland, Switzerland

Copyright: © 2009 International Union for Conservation of Nature and Natural Resources

Reproduction of this publication for educational or other non-commercial purposes is authorized without prior written permission from the copyright holder provided the source is fully acknowledged.

Reproduction of this publication for resale or other commercial purposes is prohibited without prior written permission of the copyright holder.

Citation: Reeves, R.R. and Brownell, R.L., Jr. (Editors). 2009. Indo-Pacific bottlenose dolphin assessment workshop report: Solomon Islands case study of *Tursiops aduncus*. *Occasional Paper of the Species Survival Commission*, No. 40, IUCN, Gland, Switzerland. 53 pp.

ISBN: 978-2-8317-1143-0

Cover photo: Small school of Indo-Pacific bottlenose dolphins off Kouaoua, along the east coast of New Caledonia (photograph by Claire Garrigue)

Available from: IUCN (International Union for Conservation of Nature)
Publications Services
Rue Mauverney 28
1196 Gland, Switzerland
Tel +41 22 999 0000
Fax +41 22 999 0020
books@iucn.org
www.iucn.org/publications

Venue and dates: Secretariat of the Pacific Regional Environment Programme (SPREP), Training and Education Centre, Apia, Samoa, 21-23 August 2008

Funded by: WWF (International), The Ocean Conservancy, Animal Welfare Institute, Humane Society of the United States, Whale and Dolphin Conservation Society, U. S. Marine Mammal Commission, and U. S. National Oceanic and Atmospheric Administration

TABLE OF CONTENTS

Executive Summary	i
1. Introduction	1
1.1 Purpose and scope of workshop	1
1.2 Report preparation, review and distribution	1
2. Management goals and assessment options	2
2.1 Scientific Committee of the International Whaling Commission	2
2.2 ASCOBANS	3
2.3 Potential Biological Removal	4
2.4 New Zealand Marine Mammal Management Act	4
2.5 Allowable Biological Catch (ABC) quotas for Dall's porpoise hunting in Japan	5
2.6 ETP tuna fishery bycatch	5
2.7 Summary of methods	5
2.8 General considerations	7
3. Review of <i>Tursiops</i> biology	7
3.1 Overall distribution of <i>T. aduncus</i>	7
3.2 Distribution and occurrence of <i>T. aduncus</i> around the Solomon Islands	8
3.3 Distribution of <i>T. aduncus</i> in New Caledonia	9
3.4 General abundance of <i>T. aduncus</i>	10
3.5 General population structure of <i>T. aduncus</i>	10
3.6 General habitat and ecology of <i>T. aduncus</i>	11
3.7 Life history of <i>T. aduncus</i>	12
3.8 Behaviour of <i>Tursiops</i> spp.	13
3.9 Site fidelity and tenacity (short- and long-term) of <i>Tursiops</i> spp.	14
3.10 Inter-island movements	14
4. Direct removals	14
4.1 Dolphin hunting in the Solomon Islands	14
4.2 Live-capture: global considerations	14
4.3 Live-capture: Solomon Islands	15
5. Threat factors other than direct removals	16
5.1 Incidental mortality in fisheries (bycatch)	16
5.2 Toxic effects from chemical pollution of dolphins and/or their prey	17
5.3 Modification, degradation or destruction of habitat (e.g. reefs, harbours)	17
5.4 Noise	18

6. Units to conserve	18
6.1 <i>Tursiops</i> genetics	19
6.2 Illustrative case study: spinner dolphins in French Polynesia	20
6.3 Radio-tagging and tracking	21
7. Methods to estimate population size for small cetaceans	21
7.1 Overview	21
7.2 Estimating abundance of <i>T. aduncus</i> in the Solomon Islands	22
8. Assessment algorithms	25
8.1 Population Viability Analysis (PVA)	25
9. Synthesis	29
9.1 Research and assessment plan for island-associated populations of Indo-Pacific bottlenose dolphins	29
9.2 Genetic sampling and analyses	30
9.3 Cultural and other local considerations for researchers	32
10. Conclusions	32
11. References cited	34
Annex 1: List of Participants	43
Annex 2: Workshop Agenda	45
Annex 3: Biographies of Workshop Participants	47
Annex 4: Traditional Drive Hunting of Dolphins in the Solomon Islands	51
Annex 5: Using Genetics to Assess the Sustainability of the Traditional Dolphin Hunt in the Solomon Islands – Marc Oremus	53

Executive Summary

A workshop on the assessment of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*), with the Solomon Islands as a case study, took place from 21-23 August 2008 in Apia, Samoa. It was planned and organized under the auspices of the Cetacean Specialist Group and attended by 19 invited participants from eight countries. Financial support was provided by WWF (International), The Ocean Conservancy, Animal Welfare Institute, Humane Society of the United States, Whale and Dolphin Conservation Society, U.S. Marine Mammal Commission and U.S. National Oceanic and Atmospheric Administration. The workshop was hosted by the Secretariat of the Pacific Regional Environment Programme (SPREP).

Live-capture, holding in captivity and export of Indo-Pacific bottlenose dolphins from the Solomon Islands began in 2003. These activities stimulated global interest and generated concern about the potential conservation implications. The IUCN Global Plan of Action for the Conservation of Cetaceans had stated that as a general principle, small cetaceans should not be captured or removed from a wild population unless that specific population has been assessed and shown capable of sustaining the removals. A principal goal of the present workshop was to elaborate on the elements of an assessment that would meet this standard. Participants noted that an assessment involving delineation of stock boundaries, abundance, reproductive potential, mortality and trend cannot necessarily be achieved quickly or inexpensively.

Specific topics covered by the workshop included management goals and assessment options, general biology and life history of bottlenose dolphins, forms of direct removal of dolphins from the wild, other threat factors, defining units to conserve, methods for estimating population size and assessment algorithms (e.g. population viability analysis). A framework for assessment was outlined, suggestions for genetic sampling and analyses were developed, and cultural and other local considerations for researchers working in the Pacific Islands region were summarised.

There is a need to determine the conservation status of Indo-Pacific bottlenose dolphin populations around islands where human-caused mortality or removal (direct or incidental catch) is known to be occurring. The species has a limited coastal range throughout much of the Indo-Pacific Ocean except in areas with wide continental shelves. Its near-shore distribution makes it particularly vulnerable to exploitation and other anthropogenic threats. In some regions where these dolphins have been studied, the populations have been found to be small compared to nearby open-ocean populations of common bottlenose dolphins (*T. truncatus*) and other species. The only known large concentrations (> ca. 1,000) are in regions with large shallow-water areas, e.g. Shark Bay on the western coast of Australia, North Stradbroke Island on the eastern coast of Australia and the Arabian Gulf. Given the restricted areas of potentially suitable habitat, populations of *T. aduncus* in the South Pacific islands are likely small, i.e. in the hundreds.

The government of the Solomon Islands had issued a permit for export of up to 80 dolphins per year (CITES Secretariat document AC 23 Doc.8.5) and it was reported at the workshop that the annual allowable export level was being increased to 100 dolphins of any species, but most likely to be only *T. aduncus*. If an international standard rule allowing 1% or 2% of a population to be removed annually (per IWC, ASCOBANS etc.) were applied in this instance, the local *T. aduncus* population would have to be at least 5,000 or 10,000 to sustain the permitted level of exports.

Based on the current state of knowledge of Indo-Pacific bottlenose dolphins throughout their range, as well as the information on this species in the Solomon Islands reviewed at the workshop, abundance in the area of recent live-captures appears to be well below 5,000. By the time of the workshop, an ongoing photo-identification study around Guadalcanal Island had catalogued only somewhat more than 100 individuals. Population assessment efforts need to be expanded if live-capture activities are to continue. It was concluded that the best approach to assess abundance and delineate populations would be a combination of mark-recapture analyses of photo-identification data and genetic analyses of tissue samples. It is assumed that Indo-Pacific bottlenose dolphins are not taken in the drive hunt in the Solomon Islands, but if they are, then both types of removal – live-capture and hunting – would need to be considered in any assessment of population status.

1. Introduction

The workshop was planned and organized by a steering group consisting of R.L. Brownell Jr., R.R. Reeves, N.J. Gales and W.F. Perrin (see Annex 1 for a list of participants). Brownell handled logistics and Reeves chaired the meeting in Samoa. Financial support was provided by WWF (International), The Ocean Conservancy, Animal Welfare Institute, Humane Society of the United States, Whale and Dolphin Conservation Society, U.S. Marine Mammal Commission and U.S. National Oceanic and Atmospheric Administration. The workshop was hosted by the Secretariat of the Pacific Regional Environment Programme (SPREP).

Reeves welcomed the participants and thanked L. Bell and SPREP for providing meeting facilities. With regret, it was noted that Gales and Perrin were unable to travel to Samoa, and B. Kahn, who carried out a cetacean survey in the Solomon Islands in 2004 (Kahn 2006), was unable to reach Apia due to a missed flight connection. R. Lacy, chairman of the IUCN/SSC Conservation Breeding Specialist Group, was unable to attend the meeting but contributed by collaborating with R. Wells on a series of simulation analyses to assess extinction risk (see section 8).

S. Childerhouse and B. Wilson served as rapporteurs. In addition, individual presenters provided summaries of their contributions for inclusion in the report.

1.1 Purpose and scope of workshop

Live-captures and holding in captivity of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) from the Solomon Islands starting in 2003, with exports from the Solomon Islands the same year, stimulated global interest and generated concern about the potential conservation implications of such removals (Ross *et al.* 2003a; Brownell and Reeves 2008). The IUCN Global Plan of Action for the Conservation of Cetaceans (Reeves *et al.* 2003) stated that as a general principle, small cetaceans should not be captured or removed from a wild population unless that specific population has been assessed and it has been determined that a certain level of removals can be allowed without reducing the population's long-term viability and without compromising its role in the ecosystem. The Global Plan further noted that such an assessment, including delineation of stock boundaries, abundance, reproductive potential, mortality, and status (trend), should not be expected to be achieved quickly or inexpensively. A principal goal of the present workshop was to elaborate on the elements of an assessment that would meet such a standard.

The workshop steering committee determined that the meeting should focus on scientific and technical issues relating to the conservation of populations of small cetaceans, especially Indo-Pacific bottlenose dolphins. The agenda (Annex 2) was developed around that focus and participants were selected to ensure that sufficient expertise would be present at the workshop (see Annex 3 for background information on participants). It was expected that the assessment framework developed by the workshop would be useful as a template not just for the case of Indo-Pacific bottlenose dolphins in the Solomon Islands, but also for at least some other populations of small cetaceans elsewhere.

1.2 Report preparation, review and distribution

The main conclusions of the report (see Section 10) were discussed and agreed before the meeting adjourned in Samoa. The report was assembled and edited by Reeves and Brownell following the workshop, based on notes from the rapporteurs and submissions on particular topics by participants

with relevant expertise. A complete draft of the report was circulated to all participants by e-mail, and their comments and additions were incorporated into this, the final version.

2. Management goals and assessment options

Wade provided a detailed overview of tried methods for assessing cetacean populations and determining sustainable take levels.

Takes (removals) from marine mammal populations can be assessed in a variety of ways. Although some populations are relatively well-studied, limited data are available on the majority of them. In many cases, when a new situation arises involving takes caused by human activities, essentially no data are available. In such cases, an abundance estimate can usually be obtained from a properly designed survey, allowing assessment of take levels in relation to population abundance.

The Scientific Committee (SC) of the International Whaling Commission (IWC) regularly evaluates the conservation status of populations of small cetaceans subject to direct or incidental mortality caused by human activities. Since 1995, the SC has used a simple rule based on a percentage of an abundance estimate to decide whether a particular level of take is cause for concern. Similarly, the Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS), under the Convention on Migratory Species of Wild Animals, has applied simple rules based on a percentage of an abundance estimate to evaluate bycatches of harbour porpoises (*Phocoena phocoena*) in commercial fisheries.

In the United States, a similar method has been used to evaluate human-caused mortality for marine mammal populations. The US Marine Mammal Protection Act (US MMPA) was amended in 1994 to specify the use of the Potential Biological Removal (PBR) scheme for managing removals, particularly bycatches in commercial fisheries (Wade and Angliss 1997). The PBR scheme calculates a take threshold from an abundance estimate to identify populations for which the level of take should be reduced. The PBR scheme has enabled relatively rapid assessment (requiring on the order of a few years) and has been credited for dramatically increasing the number of marine mammal populations assessed in the United States: only 12 populations had been assessed prior to 1994 whereas after passage of the amendments to the US MMPA a total of 153 populations had been assessed under the PBR scheme by 1995 (Taylor *et al.* 2000).

Management of bycatch of New Zealand sea lions (*Phocarctos hookeri*) under the New Zealand Marine Mammal Management Act has used a scheme similar to the PBR scheme, but adjusted for different management goals. Similarly, PBR-type methods are among a suite of methods proposed for evaluating bycatches of Hector's dolphins (*Cephalorhynchus hectori*) in New Zealand. Japan's National Research Institute of Far Seas Fisheries has proposed a PBR-type method to set quotas on Dall's porpoises (*Phocoenoides dalli*) hunted in Japan, and a simulation study on how to apply this method was published recently (Okamura *et al.* 2008). Finally, countries involved in the tuna purse-seine fishery in the eastern tropical Pacific (ETP) have agreed to caps (essentially quotas) on incidental mortality of dolphins in that fishery under the Agreement on the International Dolphin Conservation Program (see later). All of those methods for evaluating take levels are compared and contrasted below.

2.1 Scientific Committee of the International Whaling Commission

The SC's standing Subcommittee on Small Cetaceans regularly reviews the status of small cetaceans and evaluates whether levels of human-induced mortality are of conservation concern. After reviews in 1995 and 1996, the SC agreed that in no case should bycatches and/or directed takes exceed ½ of

the maximum growth rate of a population (R_{\max}) (IWC 1996a p. 89; 1997, p. 98). The SC further stated that R_{\max} for harbour porpoises could be lower than 4% a year, which implies a threshold of 2% or lower (IWC 1996a, p. 89). The SC agreed that takes may not be sustainable for harbour porpoise stocks where bycatch levels are greater than 2% of the abundance estimates (IWCa 1996 p. 89; 1997, p. 98). The SC also concluded that 1% of an abundance estimate represents a reasonable and precautionary threshold beyond which there should be concern about the sustainability of anthropogenic removals, and it recommended that when removals exceed 1%, further research should be undertaken to refine abundance and bycatch estimates (IWC 1996a, p. 89; 1997, p. 98). The Commission adopted the SC's recommendations for harbour porpoises, specifically noting that an estimated annual bycatch of $> 1\%$ of estimated population size indicates that further research should be undertaken immediately to clarify the status of the affected stock or stocks (IWC 1996b, p. 35). In 2001, the SC reiterated that bycatch levels greater than 2% of abundance for harbour porpoises may not be sustainable, and recommended that such bycatch levels should be reduced to sustainable levels as soon as possible (IWC 2002, p. 59).

The SC has applied the same criteria to other small cetaceans. For example, it concluded that levels of directed takes of Dall's porpoises exceeding 2% of abundance are unlikely to be sustainable and recommended that such catch levels be reduced to sustainable levels as soon as possible (IWC 2002, p. 58; 2006, p. 42). In a review of the status of the franciscana (*Pontoporia blainvillei*), a coastal small cetacean in the western South Atlantic, the SC determined that a 1% removal level was sufficient to warrant concern, and therefore expressed particular concern about the status of franciscanas in areas where the annual bycatch is estimated to exceed 1% of abundance (IWC 2005, p. 40).

2.2 ASCOBANS

ASCOBANS has used two thresholds for evaluating incidental mortality of harbour porpoises. This agreement has interpreted its aim to be "to restore and/or maintain biological or management stocks of small cetaceans at the level they would reach when there is the lowest possible anthropogenic influence" (ASCOBANS 2000, p. 94). The agreement's "short-term practical sub-objective" is "to restore and/or maintain stocks/populations to 80% or more of the carrying capacity [K]" (ASCOBANS 2000, p. 94). Based on the findings of a joint IWC/ASCOBANS Working Group, ASCOBANS (2000, p. 95) determined that an annual anthropogenic removal level greater than 1.7% of the best available estimate of population size for harbour porpoises was "unacceptable" in terms of meeting the agreement's interim objective of restoring or maintaining populations at 80% or more of K. It also defined the reduction of bycatches to less than 1% of the best available population estimate as an "intermediate precautionary objective" (ASCOBANS 2000). In other words, the advice was to reduce takes immediately to less than 1.7% and then work towards the goal of reducing takes to less than 1% of the population size.

In the 2006 ASCOBANS meeting, a recovery plan for harbour porpoise populations was agreed. It reiterated the recommendation that total anthropogenic removal should be reduced to below the threshold of "unacceptable interactions" (i.e., 1.7% of a best available abundance estimate) with the precautionary objective to reduce bycatch to less than 1% of the best available abundance estimate (ASCOBANS 2006a, p. 74). This was based on the assumption that the maximum net production of a harbour porpoise population could be lower than 4% per year, and that bycatch and abundance estimates always have associated uncertainties (ASCOBANS 2006b, p. 11).

2.3 Potential Biological Removal

Wade (1998) discussed several related thresholds for human-caused mortality designed to meet various conservation objectives. One, termed the Potential Biological Removal (PBR) level, was designed to prevent populations from declining below their Maximum Net Productivity Level (MNPL), thought to be a level between 50-80% of K (Taylor and DeMaster 1993). Fishery bycatch of small cetaceans in the United States is evaluated using the PBR (Taylor *et al.* 2000), as follows:

$$\text{PBR} = N_{\min} \cdot \frac{1}{2} R_{\max} \cdot F_R$$

Wade (1998) found that use of the 20th percentile for N_{\min} would give a 95% probability that a population would be above MNPL after 100 years. A recovery factor (F_R) of 0.5 is used for robust performance under many situations (Wade 1998) where estimates of abundance, kill, or R_{\max} are potentially biased or where there are uncertainties about population structure. If information is considered highly reliable and the population is well known, a higher recovery factor, up to a value of 1, can be used (Wade and Angliss 1997).

Although some baleen whales have shown somewhat higher rates of population growth, nearly all small cetaceans are thought to have rates of growth no higher than about 4% per year ($R_{\max}=0.04$) (Wade 1998, 2002). Certainly no dolphin population has been observed to increase at a faster rate, and aspects of their life history (such as their relatively high age of sexual maturity and low birth rate) make faster rates unlikely for dolphins (Wade 2002; Reilly and Barlow 1986). In the United States, the PBR for dolphin populations is calculated using a default growth rate value of 0.04 (Wade and Angliss 1997); a total of 56 dolphin populations have calculated PBRs and all use the value of 0.04 (Angliss and Outlaw 2008; Carretta *et al.* 2007; Waring *et al.* 2007).

Although calculated based on a minimum population estimate, the PBR can be expressed as a percentage of the best available abundance estimate (like the IWC calculations) if the precision of the abundance estimate is specified. Coefficients of variation (CVs) for cetacean abundance estimates usually fall within a range of 0.1 to 0.8. For that range of CVs, a PBR calculated using $F_R=0.5$ will represent 0.9% and 0.6%, respectively, of the best (point) estimate of abundance, and with $F_R=1.0$ it will represent 1.8% and 1.1% of the best estimate of abundance.

2.4 New Zealand Marine Mammal Management Act

Several thresholds have been calculated for managing bycatch under New Zealand's Marine Mammal Management Act. A threshold for bycatch of New Zealand sea lions (termed the MALFIRM, a Maximum Allowable Level of Fishing Related Mortality) was first set in 1995 (Harcourt 2001; Gales 1995). It was originally calculated in the same way as the PBR but with a F_R of 0.15. This value was used in order to achieve an objective that the New Zealand sea lion population would recover to 95% of K, which in turn would encourage animals to disperse and re-occupy historic rookeries where the species had been extirpated. The MALFIRM approach has evolved into a specialized, case-specific modelling effort, but the conservation objective remains similar – to manage bycatch levels so that the sea lion population remains above 90% of K, or above 90% of the level it would reach in the absence of fishery bycatch, 90% of the time in 20- and 100-year simulation runs. Assuming R_{\max} is 0.04 for a dolphin population, a threshold calculated using an F_R of 0.15 would result in a MALFIRM of 0.3% (for CV=0.1) or 0.2% (for CV=0.8) of a best abundance estimate.

Additional thresholds were calculated when the New Zealand Government released a draft Threat Management Plan for Hector's dolphins (New Zealand Ministry of Fisheries 2007). The draft plan discusses the concept of PBR as a guide to how much protection would be required to avoid further

population declines. PBR is calculated using two different values of F_R ; a value of 0.15 is suggested to promote population recovery or a value of 0.5 is suggested to prevent further decline. The draft plan also discusses different possible values of R_{max} for Hector's dolphins, including 0.04 (the default value for dolphins) as well as two lower case-specific values of 0.036 and 0.018. Slooten and Dawson (2008) repeated calculations of PBR for Hector's dolphin, using R_{max} values of 0.04 (the default) and 0.018 (estimated in Slooten and Lad 1991), with a F_R value of 0.1 (as recommended for an endangered species). Taken collectively, these suggested values for both R_{max} and F_R lead to PBR calculations ranging between 0.1%-0.9% (for $CV=0.1$) or 0.1%-0.6% (for $CV=0.8$) of a best abundance estimate.

2.5 Allowable Biological Catch (ABC) quotas for Dall's porpoise hunting in Japan

Prior to 2008, Japan's National Research Institute of Far Seas Fisheries calculated Allowable Biological Catch (ABC) levels as 4% of an abundance estimate. In 2008, it proposed to use the PBR method of Wade (1998) and scientists from the institute evaluated such an approach when applied to the Dall's porpoise hunt using a simulation modeling exercise. Okamura *et al.* (2008) found that use of a recovery factor of 0.8 in the standard PBR formula would be successful in keeping populations above MNPL for the scenarios they examined. Again assuming $R_{max}=0.04$ for a dolphin population, a recovery factor of 0.8 leads to thresholds of 1.4% (for $CV=0.1$) or 0.9% (for $CV=0.8$) of a best abundance estimate.

2.6 ETP tuna fishery bycatch

Dolphins of several species are killed during tuna purse-seine fishing in the ETP. In 1995 the governments of Belize, Colombia, Costa Rica, Ecuador, France, Honduras, Mexico, Panama, Spain, United States, Vanuatu and Venezuela reached an agreement (known as the "Declaration of Panama") to progressively reduce dolphin mortality in the ETP. The agreement set a cap on dolphin mortality equal to 0.2% of a minimum abundance estimate, with the understanding that the cap would be lowered eventually to 0.1%. The Declaration of Panama was superseded by the Agreement on the International Dolphin Conservation Program (AIDCP, <http://www.iattc.org/IDCPENG.htm>), which reaffirmed a cap on dolphin mortality of 0.1% of a minimum abundance estimate. Costa Rica, Ecuador, El Salvador, the European Union, Guatemala, Honduras, Mexico, Nicaragua, Panama, Peru, United States, Vanuatu, and Venezuela had ratified the AIDCP by August 2008 (the time of writing). Bolivia and Colombia were applying the agreement provisionally. The stated goal of the agreement is to maintain or restore the biomass of associated stocks at or above levels capable of producing the maximum sustainable yield, and to minimize the bycatch of non-target species (such as dolphins) in order to ensure long-term sustainability of all species. The cap of 0.1% of a minimum abundance estimate leads to thresholds of 0.18% (for $CV=0.1$) or 0.11% (for $CV=0.8$) of a best abundance estimate.

2.7 Summary of methods

A summary of the above approaches is presented in Table 1 where it can be seen that threshold values range from 0.1% to 2% of a best estimate of abundance, and that they are relatively consistent with one another.

Table 1. Summary of threshold values used to evaluate sustainability or acceptability of takes of marine mammals. For the PBR, the New Zealand MALFIRM and the Okamura *et al.* (2008) methods, an R_{max} value of 0.04 was used.

Method	Abundance estimate CV=0.1	Abundance estimate CV=0.8	Interpretation/recommendation if takes greater than threshold
IWC 2%	2.0%	2.0%	Immediate reduction in takes to below threshold
IWC 1%	1.0%	1.0%	Immediate research on abundance, R_{max} , and stock structure needed to clarify status of the stock
ASCOBANS 1.7%	1.7%	1.7%	Immediate reduction in takes to below threshold
ASCOBANS 1.0%	1.0%	1.0%	May not be sustainable, work towards reducing takes
PBR $F_R=1.0$	1.8%	1.1%	Used if confident no biases exist, takes unsustainable
PBR $F_R=0.5$	0.9%	0.6%	Default value when uncertainty exists, takes unsustainable
New Zealand MALFIRM	0.3%	0.2%	Immediate reduction in takes to below threshold
New Zealand Hector's dolphin PBR	0.1%-0.9%	0.1%-0.6%	Takes are unsustainable or would not allow population recovery
Okamura <i>et al.</i> (2008) $F_R=0.8$	1.4%	0.9%	Quota for hunt exceeded
ETP dolphins	0.2%	0.1%	Serves as a hard cap on dolphin mortality in the tuna purse-seine fishery, through the mechanism of individual vessel quotas within each country

For three of the methods (IWC, ASCOBANS and PBR), two thresholds are discussed, with different interpretations in each context. For these three methods, if takes exceed the higher threshold, the interpretation is to recommend an immediate reduction in takes. If takes exceed the lower threshold, there is a variety of interpretations depending on the context, but the prescriptions range from an immediate reduction in takes, to further research, to a longer-term goal of reducing takes. For four of the methods (PBR, New Zealand, Okamura *et al.* 2008, and ETP dolphins), the precision of the abundance estimate is factored into the calculation, which is extremely important.

Most of the thresholds are well below 2%, particularly for situations where the abundance estimate is relatively imprecise (CV=0.8). Differences among the methods reflect the differences in stated management or conservation goals. For example, getting a population to recover to at least 50% of K (the PBR goal) is a different goal than getting it to at least 80% of K (the ASCOBANS goal).

Several of the methods are based on PBR-type calculations. In a review of indices of sustainability for exploited populations, Milner-Gulland and Akçakaya (2001) found that PBR-type calculations performed well in all tests considered they and described PBR as highly promising in terms of its ability to reduce the risk of extinction to acceptably low levels.

Rates of anthropogenic mortality greater than 2% are considered unsustainable by all methods, and removal rates higher than 1% are considered problematic by seven of the ten methods reviewed. The

IWC's two-tiered system is the nearest thing available to a simple "international standard." It is reasonably interpreted to mean that takes of more than 2% of the population size are unacceptable and cause for an immediate reduction, and that takes of more than 1% are cause for concern and signal the immediate need for research to assess the status of the stock. All of the other methods reviewed imply lower thresholds, so take levels of anywhere between 0.1% and 2% are subject to different interpretations under different management goals and systems. The ASCOBANS and ETP dolphin thresholds have been accepted by the respective signatory states. The ASCOBANS standard is similar to but higher than the IWC's, whereas the ETP dolphin standard is much higher than the IWC's. (Note that standards are "higher" when the triggering or threshold levels are lower.)

All of the methods require at least one abundance estimate so that an upper threshold level of removals can be set. Great caution is indicated if no abundance estimate is available and if the population is known or likely to have a limited (e.g. coastal) distribution (e.g. Hector's dolphin). It is important to recognize that Indo-Pacific bottlenose dolphins generally occur in relatively small populations compared to the more pelagic species such as Dall's porpoise or the spinner and spotted dolphins (*Stenella longirostris* and *S. attenuata*). Moreover, small populations can be at risk of extinction and may require further lowering of the thresholds on removals (Slooten and Wade 2007). For example, in the United States, PBR levels for populations of species listed as endangered are calculated with $F_R=0.1$ to allow these small populations to recover rapidly, thus reducing their risk of extinction (Wade and Angliss 1997, Wade 1998). Additionally, in cases where a population is small and could be declining (e.g. the North Atlantic right whale, *Eubalaena glacialis*, with a minimum population size of only 313; Waring *et al.* 2007), the PBR value is set to zero to encourage complete protection.

2.8 General considerations

Japan's quota on Dall's porpoises is the only example where a PBR-type method has been applied (theoretically) to a direct catch rather than a bycatch. One potentially important consideration is that in some direct hunts, the age and sex composition of the catch can be stipulated (e.g. in its schedule of whaling regulations, the IWC prohibits the taking of calves), which is not the case with bycatch. Most of the methods described in section 2.7 (above) set limits on removals assuming a random catch of individuals from the population although this is rarely made explicit. Another issue that may be important in setting catch limits for populations of small cetaceans is social structure. The selective removal of individuals or classes that are important to the functioning of social units (e.g. large male pilot whales in Japan) or to reproduction (e.g. live-capture fisheries that target young females) could have a disproportionate impact on the population. Further, the timing of the catch efforts may be important; for example, catching during the calving season could be more socially disruptive than catching during other times of the year. Finally, the spatial aspects of the removals may be relevant to any assessment of the potential impacts on the population. These issues are not necessarily addressed by PBR-type assessment methods, although they may be covered to some degree in the definition of Unit to Conserve (see Section 6, below).

3. Review of *Tursiops* biology

3.1 Overall distribution of *T. aduncus*

Due to decades of uncertainty about the status of *T. aduncus* as a distinct species, the information on its distribution is limited and patchy (Wang and Yang, 2009). In general, the species appears to be distributed widely in coastal waters from around Cape Town, South Africa, northwards along the eastern side of Africa and including the offshore islands (e.g. Reunion, Mauritius, Madagascar and the Seychelles) (Best 2007), throughout the Red Sea, eastward in coastal and shallow offshore waters of

the northern Indian Ocean to the Solomon Islands and New Caledonia in the western South Pacific and around most of the coastline of Australia (Kemper 2004) and in most of the coastal waters of Southeast Asia northward to the northern-central coast of Honshu, Japan. The distribution appears to be discontinuous. For example, several small resident populations exist off Kyushu and around oceanic islands off Japan. The approximate worldwide distribution is shown in Figure 1.

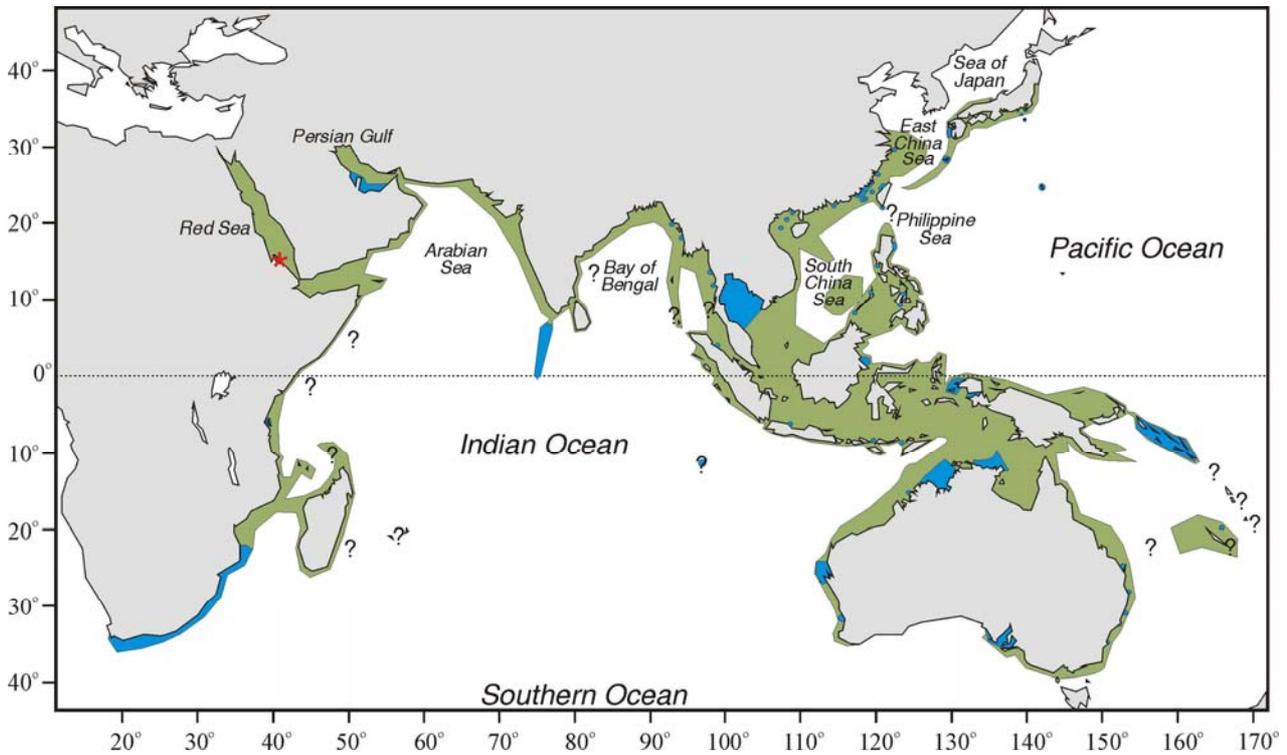


Figure 1. Approximate range of Indo-Pacific bottlenose dolphins, *Tursiops aduncus*, reprinted from Wang and Yang (2009) with the permission of the authors and Academic Press. The red star in the Red Sea represents the type location. Blue indicates areas where the distribution is well-known and green indicates areas where it is less well-known. Information is limited and patchy so question marks were placed in some locations to indicate uncertainty. For additional details, updates and references, see sections 3.1 and 3.3 of this report.

3.2 Distribution and occurrence of *T. aduncus* around the Solomon Islands

Defran summarized methods and results of his work to date from the Solomon Island Dolphin Abundance Project. *Tursiops aduncus* is the focal species for this project. Work on the project began with four boat-based photo-identification surveys carried out along the northern coast of Guadalcanal during the summer of 2005. Work resumed in the summer of 2007 and continues to the present (August 2008). All told, 35 photo-identification surveys were conducted between June 2005 and July 2008, distributed across four survey periods (i.e. 1 survey period = 1 Solomon Islands trip by Defran). Near-shore surveys of northern Guadalcanal (east and west of Honiara), covering the entire 160 km northern coastline of the island, have continued since 2005. A number of additional surveys have been conducted across the deep waters between Guadalcanal and the Florida Islands, along the northern and southern borders of the Florida Islands, and around Savo Island. Two “long-range” surveys have been carried out to the extreme eastern end of Guadalcanal, near the resort area of Marau.

One goal of the initial surveys was to use the developing photo-identification catalogue to examine aspects of *T. aduncus* site fidelity and home range. Such information will provide a useful empirical basis for final decisions on how to define the study area. Photo-identification data analysed thus far include a total of 113 distinctively marked individuals. Five of these individuals were identified during surveys carried out in 2005, 2007 and 2008. Seventeen individuals were identified during adjacent study years (i.e. 2005 and 2007, 2007 and 2008) and 40 were photographed more than once within at least one of the three analysed survey trips (10 to 21 days long). These data suggest the occurrence of at least short- or medium-term site fidelity. Twenty-three of 26 dolphins identified near Marau on 25 March 2008 were again photographed 10 days later east of Honiara, a distance of approximately 113 km. This finding suggests that for some dolphins, the home range includes much of the northern Guadalcanal coastline. The scheduled project duration is three years (2008 to 2010) and a major goal is to produce an abundance estimate for the Guadalcanal population of *T. aduncus* using a mark-recapture analysis.

During discussion, Defran stated that he had received reports of bottlenose dolphins in other areas of the Solomon Islands (e.g. Florida Islands) but the species identification was uncertain. He noted that all sightings of *T. aduncus*, except one, during his surveys had been inshore of the survey vessel (which generally travels about 500-750 m offshore) and in water 40-50 m deep.

A large-scale, interdisciplinary marine assessment was conducted in the western provinces of the Solomon Islands in 2004. This work covered over 2,400 nmi and included a dedicated marine mammal component (Kahn 2006, 2007a). The visual and acoustic cetacean survey spanned over 36 days and included 160 active survey hours of passage between site-based activities. Dedicated visual survey effort covered a total of ~1,228 nmi and, in addition, 49 listening stations with dual hydrophones were deployed. A total of 11 cetacean species were identified in 52 encounters. At least 815 individual cetaceans were counted. The survey effort in the “coastal habitat zone,” which is considered the principal habitat for *T. aduncus*, was substantial (67.5 hrs), comprising of more than 40 % of the total effort (Kahn 2006, 2007a). Despite this relatively large amount of effort throughout the western provinces, there was only one confirmed sighting of *T. aduncus*, and this was off Noro Passage, near Gizo off New Georgia Island, which is northwest of Guadalcanal Island (Benjamin Kahn, pers. comm. to Reeves, October 2008). This sighting involved a group of 11 animals; no calves were observed.

Workshop participants urged caution when attempting to predict where *T. aduncus* are likely to be found. In Japan, at the extreme northern end of the species’ range, the distribution is patchy and discontinuous but this may not be the case in the Solomons. Wang noted that *T. aduncus* appear fairly plastic in their habitat selection and this makes it difficult to judge the types of habitat where they might be found in the Solomon Islands. Defran reported having seen them immediately offshore of two logging sites where deep water comes very close to shore.

3.3 Distribution of *T. aduncus* in New Caledonia

Garrigue and Oremus provided information on the distribution of bottlenose dolphins in New Caledonia. Based on records obtained opportunistically from 1995 to 2007, it is clear that both species are present but most sightings have been of *T. aduncus* and these were confined to coastal waters. The data show that *T. aduncus* occur inside the lagoons all around the main island of New Caledonia. New Caledonia represents the eastern limit of the known geographic range of this species in the South Pacific.

An ongoing series of dedicated surveys for bottlenose dolphins in four locations around New Caledonia, two on the west coast and two on the east coast, began in early 2008. Sampling effort to

date consists of 49 days during which 35 groups totalling more than 167 dolphins were seen. A total of 47 skin samples have been collected and a photo-identification catalogue of more than 250 different individuals (including pre-2008 opportunistic data) has been compiled. On the west coast, there has been sampling effort for five days every month since February (N=36 days), with 16 groups observed totalling 82 dolphins. Ten groups (37 dolphins) have been observed in the northern area and nine groups (45 dolphins) in the southern area. The distance between the northern and southern groups was about 30 nmi. Thus far, no individual has been photo-identified in both the northern and southern areas. Groups of dolphins have been encountered in various kinds of habitat including mangroves, areas with either muddy or white sand bottom, and on or near back reefs or fringing reefs. On the east coast, there have been only 13 days of sampling effort – 8 in July and 5 in August. Sixteen groups – 12 in the north and four in the south – have been seen, totalling more than 85 dolphins. The distance between locations along the east coast is roughly 35 nmi. Some individuals from the northern area have been sighted in the southern one, and groups have been encountered in the coastal part of the lagoon, in bays, and close to fringing or intermediate reefs.

3.4 General abundance of *T. aduncus*

There is no abundance estimate for the species population, but available information on numbers in local areas was summarised by Wang and Yang (2009). In Japan, there is an estimate of 218 dolphins in the Amakusa-Shimoshima (Kyushu) population (Shirakihara *et al.* 2002) and another of at least 160 in the Mikura Island population (Kogi *et al.* 2004). In Australian waters, there are estimates of > 600 in the Shark Bay population on the west coast, 700 to 1000 (Chilvers and Corkeron 2003) in the Point Lookout region (North Stradbroke Island, Queensland), 818 in Moreton Bay on the east coast (estimated for 1998) (Lukoschek and Chilvers 2008) and < 100 in the estuaries of the Clarence and Richmond Rivers in northern New South Wales (Furry and Harrison 2008). A resident population in the waters of Zanzibar (Tanzania) was estimated to contain between 136 and 179 dolphins (Stensland *et al.* 2006). For dolphins in the waters of Taiwan and the northeastern Philippines, there are no abundance estimates but populations appear small (Wang and Yang 2005; J.Y. Wang, pers. comm.). For a portion of the western Taiwan Strait between Xiamen and Dongshan (China), the density was estimated to be < 5 dolphins per 100 km² (Yang and Zhou, 1997; Yang *et al.*, 2000). In some coastal areas (e.g., south-eastern coast of Africa – Ross, 1977, 1984; Arabian Gulf – Preen, 2004), *T. aduncus* can be the most commonly recorded cetacean species.

Limited information suggests that *T. aduncus* populations have experienced major declines in the Arabian Gulf (Preen 2004) and in Vietnamese (cf. Smith *et al.* 1997) and Chinese waters (J.Y. Wang, pers. comm.), likely as a result of direct hunting and bycatch in fisheries. Even in the relatively undisturbed waters of Shark Bay, Western Australia, a decline in the dolphin population has been reported, and it has been suggested that the decline is related at least in part to disturbance by dolphin-oriented tourism (Bejder *et al.* 2006), usually considered a low-impact activity.

3.5 General population structure of *T. aduncus*

Little information about population structure exists but in general, the species appears to be composed of small, local populations that are largely or entirely isolated from each other (Wang and Yang 2009). Indo-Pacific bottlenose dolphins appear to exhibit strong year-round residency and natal philopatry in both sexes, but males are likely more dispersive than females (Möller and Beherengaray 2004). There are regional differences in body size, spotting patterns and acoustics. Dolphins from the northern Philippines, Solomon Islands, Taiwan and Japan are generally similar in appearance. Those from Indonesia, Western Australia and South Africa look “stubbier” and have shorter beaks and smaller bodies. Dolphins in the western North Pacific appear larger than those in other regions, reaching a maximum body length of about 2.7 m. Based on osteological and pigmentation differences, dolphins from Natal and the eastern Cape of South Africa were considered to belong to

different, year-round resident populations (Ross, 1977, 1984). The intensity of ventral spotting and the location of spotting on the body appear to vary regionally, but the overall development of spotting is similar across regions. Ventral spotting appears to coincide with the onset of sexual maturation and becomes more intense with age and therefore may indicate maturity status to conspecifics. In some populations, dolphins as short as 1.6 m may begin to exhibit spotting and become intensely spotted before they reach a length of 2.2 m, whereas in other populations the spots may not appear until at least 2.2 m. In some populations, the animals apparently are unspotted (e.g. Jervis Bay and Port Stephens, New South Wales, south-eastern Australia) although it is important to recognize that species identification remains unresolved in some areas (e.g. south-eastern Australia; Möller *et al.* 2008). Morisaka *et al.* (2005) found that whistle characteristics in three different populations in Japan could be distinguished from each other. Natoli *et al.* (2004) found what could be interpreted to be species-level genetic differences between dolphins from South Africa and Taiwan and concluded that *T. aduncus* may be polyphyletic.

3.6 General habitat and ecology of *T. aduncus*

Indo-Pacific bottlenose dolphins are found primarily in continental shelf waters (<200m deep) near shore and in areas with rocky or coral reefs, sandy or soft bottoms, or seagrass beds. Although they may be concentrated in areas where there is estuarine influence, they do not seem to enter far into the muddy, turbid waters of estuaries. Small populations also occur in the inshore waters of some small oceanic islands. Though the species is generally considered coastal, there are infrequent reports of Indo-Pacific bottlenose dolphins moving across deep oceanic waters. In South Africa, where this species has been studied for many years, Indo-Pacific bottlenose dolphins are found “almost exclusively in water less than 30 m deep” (Best 2007). The species distribution is centred in tropical to warm temperate waters of the Indian and western Pacific oceans, but populations also exist in cooler waters in Japan, northern China, southern Australia and southern Africa. Sea surface temperatures where *T. aduncus* have been observed varied from 12°C (possibly less) to more than 30°C; most observations have been in waters between 20° and 30°C.

Indo-Pacific bottlenose dolphins occur in the same areas as some other species of small odontocetes, including: *T. truncatus*, *Sousa chinensis*, *Neophocaena phocaenoides*, *Stenella longirostris*, *S. attenuata* and *Orcaella* spp. Where sympatric with *T. truncatus* (e.g. the waters of central and southern China, western and southern Taiwan, the southern half of Japan, Philippines, Australia, South Africa), *T. aduncus* is the more coastal of the two species. Where *T. aduncus* is sympatric with *S. chinensis*, *S. chinensis* is the more coastal species, but it should be noted that both species are taken incidentally in, for example, anti-shark nets set along the coast of KwaZulu-Natal, South Africa, approximately 500 m from shore (Best 2007).

The primary known prey of *T. aduncus* are benthic and reef-dwelling fishes and cephalopods (e.g. Ross, 1977, 1984) but some pelagic and epipelagic species are also consumed. Some of the families of prey that have been recorded include the fishes Belontiidae, Mugilidae, Sciaenidae, and Engraulidae and the cephalopods Sepioteuthidae, Sepiidae, Sepiolidae, Loliginidae and Octopodidae. A considerable part of the diet of Indo-Pacific bottlenose dolphins in the waters of oceanic islands appears to consist of epipelagic and mesopelagic fish and cephalopods but benthic crustaceans can also contribute substantially (Kakuda *et al.* 2002). Although rare, small benthic sharks have also been recorded as prey. Where examined, there appears to be little overlap in prey species between sympatric populations of *T. aduncus* and *T. truncatus*.

Little is known about predation on *T. aduncus*, but sharks are a main cause of mortality for some populations. The main predatory sharks are the tiger shark (*Galeocerdo cuvieri*), white shark (*Carcharodon carcharias*), bull shark (*Carcharhinus leucas*) and dusky shark (*Carcharhinus*

obscurus). The frequency of shark bites is very high in some regions (e.g. >74% of the non-calf dolphins in Shark Bay bear scars – Heithaus 2001) but much lower in others (e.g. about 37% and 10-20% of the dolphins in Moreton Bay, eastern Australia and in South African waters, respectively, have shark wounds, but it is uncertain if these data include both *T. aduncus* and *T. truncatus*). There are no records of predation by killer whales. Reports exist of bottlenose dolphins dying as a result of accidental injuries caused by needlefish and the spines of stingrays.

Few parasites and other pathogens have been recorded for *T. aduncus* (e.g. see Kakuda *et al.* 2002) compared with other species of small cetaceans, but this is probably related to research effort. Two kinds of ectoparasite – the barnacle *Xenobalanus globicipitis* and cyamids – have been observed on *T. aduncus*, and small sharks (e.g. *Isistius* sp.) may function as ectoparasites (or partial predators) by taking small bites out of dolphins living around oceanic islands (e.g. Mikura Island). The endoparasite fauna includes nematodes in the pterygoid sinuses (possibly *Crassicauda* sp.) and stomach (likely *Anisakis* sp.), tapeworms in the intestines, the nematode *Halocercus lagenorhynchi* in the lungs and respiratory tract, cestodes of the genus *Phyllobothrium* sp. in the blubber and possibly *Monorygma* sp. internally. Serological studies have revealed that dolphins in the Solomon Islands are likely exposed to *Toxoplasma gondii* (Omata *et al.* 2005) and morbillivirus (Van Bressem *et al.* 2001).

3.7 Life history of *T. aduncus*

Much of the data on life history for *T. aduncus* comes from studies of photo-identified dolphins at sites including Shark Bay, Western Australia (e.g., Connor *et al.* 2000), Mikura Island, Japan (Kogi *et al.* 2004), and Port River, Australia (Steiner and Bossley 2008). Although few data are available, the values reported from different sites are similar (Wang and Yang 2009; Table 2). Demographic and life history values reported for *T. aduncus* are largely within the ranges reported for *T. truncatus* (Wells and Scott 1999, 2002). A notable and important exception is the 12-15 year age at first reproduction for females, as reported for *T. aduncus* in Shark Bay (Connor *et al.* 2000). The implications of this comparatively late onset of maturity (as compared to *T. truncatus*, for which age at first reproduction is 8-10 years; Wells and Scott 1999) for potential population growth are difficult to evaluate in the absence of information on female reproductive lifespan and age-specific fecundity. Also, it is important to recognize that the large difference, while true for the study sites, may not hold for populations of the two species in other areas.

Table 2. Life history parameters for *Tursiops aduncus* (na = not available). (cont' next page)

Parameter	Study Site	Estimate	Source
Crude annual birth rate:	Port River, Australia	0.064	Steiner and Bossley (2008)
	Mikura Island, Japan	0.071	Kogi <i>et al.</i> (2004)
Mean fecundity rate:	Mikura Island, Japan	0.239	Kogi <i>et al.</i> (2004)
Mean recruitment rate:	Mikura Island, Japan	0.068	Kogi <i>et al.</i> (2004)
First-year mortality rate:	Shark Bay, Australia	0.24 (non-provisioned)	Mann <i>et al.</i> (2000)
	Port River, Australia	0.30	Steiner and Bossley (2008)
	Mikura Island, Japan	0.13	Kogi <i>et al.</i> (2004)
Calf mortality rate:	Shark Bay, Australia	0.40 (non-provisioned)	Mann <i>et al.</i> (2000)
	Port River, Australia	0.46	Steiner and Bossley (2008)
Age at first reproduction, female:	Shark Bay, Australia	12-15 yrs	Mann <i>et al.</i> (2000)
Maximum age, female reproduction:		na	

Parameter	Study Site	Estimate	Source
Inter-birth interval:	Shark Bay, Australia	3.0-6.2 yrs (mean = 4.6)	Mann <i>et al.</i> (2000)
	Port Royal, Australia	2.9-6.0 yrs (mean = 3.8)	Steiner and Bossley (2008)
	Mikura Island, Japan	3.0-5.0 yrs (mean = 3.4)	Kogi <i>et al.</i> (2004)
Lifetime calf production:		na	
Age at first reproduction, male:		10-15 yrs	Wang and Yang (2009)
Maximum age (estimated):		40+ yrs	Wang and Yang (2009)
Maximum age captive		37 yrs	Best (2007)[captive-born]
Immigration/emigration rates:		low	Wang and Yang (2009)
Population growth rate:		na	

3.8 Behaviour of *Tursiops spp.*

Anthropogenic removals of dolphins potentially affect the reproductive success of the remaining animals in the wild through disruption of long-established behavioural and social patterns and reduction in numbers of potential associates. Both *T. truncatus* and *T. aduncus* have demonstrated complex feeding patterns that appear to be transmitted from mother to young and in some cases horizontally throughout societies by observational learning (Connor *et al.* 2000; Chilvers and Corkeron 2001; Wells 2003). Social structure has been described in detail for *T. truncatus* in Sarasota Bay, Florida, and for *T. aduncus* in Australia and elsewhere (Wells *et al.* 1987; Wells 1991, 2003; Wells and Scott 1999; Connor *et al.* 2000, 2006; Möller *et al.* 2001, 2006). Although the details vary between species and from site to site, the Sarasota and Australia dolphins all exhibit complex patterns of interaction associated with long-term relationships between individuals and a high degree of site fidelity. In Sarasota Bay, resident dolphins span at least five generations. Social groups of both species may include kin but are not based on familial relationships. The exception to this rule is the prolonged period (3-6 years) of mother-calf association, which extends well beyond nutritional weaning and involves an extended period of learning by calves.

In at least portions of the ranges of both species, males develop strong alliances with one or more other males, typically unrelated, that can last for the duration of an individual's adult life. The importance of alliance formation is indicated by the efforts made to form new alliances when one member is lost (Wells 2003). In Sarasota Bay, members of long-term male pairs have demonstrated higher reproductive success than unpaired males (Wells 2003). In Australia, *T. aduncus* male alliances cooperate to obtain access to females, often through agonistic interactions with other single or cooperating alliances (Connor *et al.* 2000). Removal of males can reduce the potential for males remaining in the wild to find suitable partners.

In Sarasota Bay, reproductive success is related to the size of nursery groups (Wells 2000). Females raising calves in smaller groups, as might be the case following the removal of females, demonstrated significantly lower reproductive success than females of similar age raising their young in larger groups. Similarly, more successful females reared their young in more stable groups, as indicated by significant differences in social association patterns (Wells 2000). Experienced mothers demonstrated the greatest reproductive success, and other experienced mothers were among their closest associates (Wells 2003). Reductions in the numbers of available females can reduce the level of protection and learning opportunities for calves, and for young mothers.

3.9 Site fidelity and tenacity (short- and long-term) of *Tursiops* spp.

Site fidelity of *T. truncatus* has been studied in a variety of locations. The species has been found to occur in a diversity of modes, from locally resident through seasonally migrating, nomadic, gradually shifting, episodically shifting and seemingly erratic. In specific locations, the local dolphin groups may exhibit several of these modes simultaneously (for example, there may be resident individuals and seasonal visitors in the same area at the same time). There is much less information on site fidelity of *T. aduncus*. However, local residency (e.g. as in Japan and Western Australia) may prove to be more typical because there is less seasonal climatic variation in lower-latitude habitats. Environmental productivity is likely a significant determinant of whether a single location can sustain a resident population; it may act in combination with cultural aspects such as local adaptation of foraging tactics.

3.10 Inter-island movements

In a long-term study of photo-identified common bottlenose dolphins in Hawaii (n = 336 distinctively marked individuals), Baird *et al.* (in press) found evidence of multiple, small, demographically independent, island-associated populations. The photo-identification evidence is consistent with initial genetic analyses that support the idea of demographically independent populations (R.W. Baird, pers. comm.). Baird *et al.* (in press) suggest that the extent of movement of dolphins among islands within an oceanic archipelago is related to ecological circumstances. Given that waters surrounding the main Hawaiian Islands are oligotrophic, the enhanced productivity near island shores may encourage formation of coastal, island-associated populations. The comparatively extensive movements of common bottlenose dolphins around oceanic Cocos Island, Costa Rica (Acevedo-Gutierrez 1999) might be explained largely by the much greater productivity of surrounding waters there. In Bermuda, where common bottlenose dolphins regularly move from shallow (<200m) to deep (>1,000m) water, with linear ranges of at least 100 km (Klatsky *et al.* 2007), much less shallow-water habitat is available and the distances between islands are much shorter than in Hawaii.

At the workshop, Baird suggested that four factors may influence movements and site fidelity of island-associated populations of small cetaceans, as follows: productivity of habitat, size of available (shallow-water) habitat, distance among islands in combination with depth of channels, and the productivity gradient between near-shore and offshore waters.

4. Direct removals

4.1 Dolphin hunting in the Solomon Islands

Miller summarized the literature on dolphin hunting in the Solomon Islands (based largely on Takekawa 1996a, 1996b; Reeves *et al.* 1999; Kahn 2006, 2007a). Because there is no evidence to indicate that bottlenose dolphins have been regular targets of the drive hunt, it was decided to include the information summarized by participants and presented at the workshop as an annex to the report rather than including it in the main body of the report. See Annex 4 for more on this topic.

4.2 Live-capture: global considerations

Bottlenose dolphins, primarily *T. truncatus*, are the most commonly held cetaceans in zoological park settings, research facilities and military compounds, largely because they occur close to shore and can be captured relatively easily, they are easy to train, and they survive in captivity better than most other cetaceans (Wells and Scott 1999). The first display occurred in the late 1800s in England, and the first sustained colony was established at Marineland of Florida in the late 1930s. Facilities for

the public display of dolphins developed rapidly over the next 50 years, and nearly 1000 dolphins were removed from the waters of the south-eastern United States alone to support this development (Leatherwood and Reeves 1982). Similar facilities were developed in other parts of the world, especially Europe. Improved knowledge of husbandry and medical care led to increasing survivorship of captive dolphins and successful captive breeding programmes in some countries, such as the United States.

As it became possible to sustain captive populations through breeding, including cooperative breeding across facilities to maximize genetic diversity, pressure for removals from the wild declined. In the late 1980s, facilities in the United States implemented a voluntary moratorium on collection of bottlenose dolphins from the wild, and this remains in place. However, demand for wild-caught bottlenose dolphins (*T. truncatus* or *T. aduncus*) continues in other parts of the world. Since the 1990s, with the advent and rapid development around the world of highly profitable swim-with-the-dolphins interactive programmes, the increased demand for captive dolphins has outpaced the production ability of captive breeding programmes. Currently, dolphins are being supplied through live-capture operations in several countries, most notably Cuba, Japan and the Solomon Islands. In the recent past, Mexico, Russia and Taiwan were also important sources of live bottlenose dolphins. The total number of dolphins removed annually from each of those sites is unclear (for a discussion of the Solomon Islands, see 4.3 below). At least in Southeast Asia, there is a general preference in the captivity market for *T. aduncus* over *T. truncatus*, and even within *T. aduncus*, there seems to be a preference for animals from certain regions (J.Y. Wang, pers. comm.).

4.3 Live-capture: Solomon Islands

According to Kahn (2004, 2006), in 2002-2003 a local company with a dolphin holding facility near Honiara requested that 45-55 pantropical spotted dolphins taken in the drive hunt at Fanalei be kept alive and penned in a local bay. Of these, 12 were transported by a big vessel or barge to a display facility in the Florida Islands, near Honiara, apparently in early 2003. Ten of the dolphins died during transport and another died in the holding pen some time after arrival. A team from the IUCN/SSC Cetacean Specialist Group and Veterinary Specialist Group visited the facility at Gavutu in September 2003, soon after the first export shipment of 28 *T. aduncus* to Mexico had taken place (Ross *et al.* 2003a, 2003b). They observed 24 dolphins at Gavutu, one of which was a pantropical spotted dolphin, the others of which were mostly or entirely Indo-Pacific bottlenose dolphins. They also learned of additional dolphins that had either been released or transferred to a facility at Honiara prior to the site visit. The team observed 17 dolphins, all *T. aduncus*, at the Honiara facility. Therefore, 41 live dolphins were observed at the two facilities visited in September 2003, and these were in addition to the 28 exported to Mexico earlier that year. It is of interest to note that serum samples (to test for antibodies to *Toxoplasma*) were collected from 58 dolphins at Gavutu in 2003 (Omata *et al.* 2005).

The export of dolphins was banned by the Solomon Islands government after the controversial shipment to Mexico in 2003 and many, if not all, of the animals being held in the Gavutu and Honiara facilities (and that had not died or escaped) were subsequently released. Robert Satu (a local dolphin collector) challenged the export ban in court and it was overturned, such that the Ministry of Fisheries now allows up to 100 dolphins, of any species, to be exported per year. Apparently, more animals were captured prior to the second shipment of 28 dolphins in 2007, this time to Dubai, United Arab Emirates. A new holding facility was established in Honiara in 2007 and participants noted that some dolphins may have been held in that facility at the time of the workshop.

Licences are issued, for a fee of S\$10,000 (US\$1,400), that allow for the capture and export of dolphins. Applications for new licenses are subject to review by the Foreign Investment Board. The

tax revenue (10% of sale) realised from the export of 28 dolphins to Mexico in July 2003 was reportedly S\$1.5m (US\$210,000). This would mean that each dolphin exported was worth US\$7500 to the Solomon Islands government, which implies that the sale price was US\$75,000 per dolphin. The realised tax revenue for the 2007 export to the UAE is not known.

The workshop was advised that the person with overall responsibility for the capture and export of dolphins is Dr Christian Ramofafia (cramofafia@fisheries.gov.sb), Permanent Secretary of the Ministry of Fisheries and Marine Resources.

5. Threat factors other than direct removals

Any rigorous assessment of a wild population's status (e.g. as part of a "non detriment finding" to support a CITES export permit) needs to incorporate consideration of not only direct removals under permit, but also other sources of human-caused mortality or reduced productivity for that population. It must be assumed that various threats in addition to direct hunting deserve consideration in many areas, including the Pacific Islands Region (Miller 2007; SPREP 2007). Several of the relevant threat factors were discussed briefly at the workshop.

5.1 Incidental mortality in fisheries (bycatch)

Estimates of cetacean bycatch in the Pacific Islands Region are limited by the relatively small amount of monitoring that has taken place onboard fishing vessels. Onboard observer programmes do exist in the region but their overall coverage is far from comprehensive. On average, less than 1% of all longline fishing vessels operating in western, central and southern Pacific waters had independent observers aboard between 1987 and 2000 (Lawson 2001). Between 1994 and 2000, the maximum observer coverage on purse-seiners was only 5%, and for a single year of coverage (1988) observers were present aboard line-and-pole boats in the Solomon Islands for just 2% of total fishing trips (Lawson 2001). Such levels of observer coverage are inadequate to reflect the actual bycatch situation. Among the major gaps in current observer coverage are data from distant-water longliners from Korea and Taiwan and from Japanese vessels, including longliners, fishing in international waters. Coverage of certain domestic fleets of Pacific Island nations has also been poor. It is often asserted that the bycatch of domestic fleets is less than that of distant foreign fleets (Chapman 2001), but the limited datasets fail to either confirm or refute such claims. In any event, for Indo-Pacific bottlenose dolphins associated with islands, most bycatch probably occurs in coastal fisheries.

It is always possible that bycatch will occur when set or drifting gillnets are deployed in areas inhabited by cetaceans. For example, a Taiwanese driftnet fishery in the Arafura and Timor Seas along the northern coast of Australia killed an estimated 14,000 small cetaceans (of which approximately 60% were *Tursiops* sp., likely *T. aduncus*) in just 4½ years of operation (Harwood and Hembree 1987). Such high catches of *T. aduncus* would probably be explained by the fact that the large, relatively shallow area north of Australia is suitable habitat for this species. The Taiwanese driftnet fishery no longer operates in the area.

There is little explicit information about bycatch in the Solomon Islands although it is known that some gill-netting for reef fish occurs. Purse-seine vessels operate in the Solomon Islands EEZ, although most of the larger vessels deploy FADs (fish aggregation devices) and set on them rather than on dolphin schools as in the eastern tropical Pacific (note: FAD usage is being banned for some parts of the year under the Nauru Agreement). Fishermen who have relocated (since the 1950s) from villages in northern Malaita to establish a "Fishing Village" in the vicinity of Honiara (Akimichi 1992) reportedly engage in "both subsistence and commercial fishing" (Akimichi 1991). They use purse seines, gill nets and lines, and they sell much of their catch to town dwellers. Akimichi (1992)

reported that nine Risso's dolphins (*Grampus griseus*) were taken in purse seines in July 1990 near the Fishing Village. The meat was either consumed domestically or sold in the Honiara town market while the teeth were either kept by urban dwellers or given as gifts to kinsmen in the Fishing Village of Honiara and Funa'afou.

Since the workshop, Brownell has determined that the Risso's dolphins referred to by Akimichi (1992) were instead Indo-Pacific bottlenose dolphins. The catch was described by Shimura (1990) in a popular Japanese journal. Brownell met with Shimura in Tokyo in late September 2008 and she told him that she had collected the skulls from six of the nine dolphins and shipped them to the National Science Museum, Shinjuku, Tokyo, Japan, where their identification as *T. aduncus* was confirmed (Kurihara and Oda 2007).

5.2 Toxic effects from chemical pollution of dolphins and/or their prey

Direct cause-and-effect relationships between environmental contaminants and dolphin mortality have not been shown to date, but the weight of evidence suggests that high tissue concentrations of some pollutants, including heavy metals, some persistent organochlorine compounds including PCBs and pesticides (POPs), and emerging chemicals such as brominated fire retardants can have reproductive and/or health impacts (O'Shea 1999; Kannan *et al.* 2000; Schwacke *et al.* 2002). Little information is available on environmental contaminants in *T. aduncus*. In *T. truncatus*, males accumulate POPs throughout their lives, reaching tissue concentrations that are more than an order of magnitude greater than the theoretical threshold for health or reproductive effects (Kannan *et al.* 2000; Schwacke *et al.* 2002; Wells *et al.* 2005). Females, with maximum lifespans that exceed those of males, depurate POPs through lactation, reducing their tissue concentrations to levels below that threshold (Cockcroft *et al.* 1989; Wells *et al.* 2005). First-born offspring receive high doses of POPs through milk, and their mortality rate is higher than that of subsequent calves, which receive lower doses of contaminants accumulated in the mother's tissues over fewer years (Wells *et al.* 2005). Risk assessments have related increased calf mortality to contaminants at several sites in the south-eastern United States (Schwacke *et al.* 2002). Proximity to industrialized or agricultural areas is not necessary for bottlenose dolphins to accumulate contaminants. A small number of samples were collected from bottlenose dolphins off the oceanic island of Bermuda, and they demonstrated exposure to many of the same environmental contaminants as coastal dolphins living near the U.S. mainland (Houde *et al.* 2006). In some cases, concentrations were comparable. Deposition of airborne contaminants likely plays a major role in the distribution of contaminants to distant sites.

Nothing is known about levels of pollutants in *T. aduncus* in the Solomon Islands. The workshop was unaware of any major sources of pollutants in the region. However, as mentioned above, dolphins can accumulate pollutants at a great distance from the source, and improper disposal and dumping of toxic wastes is known to occur across the Pacific Islands Region.

5.3 Modification, degradation or destruction of habitat (e.g. reefs, harbours)

The workshop had almost no information on this problem in the region, and it was agreed that no meaningful quantitative evaluation of the risks to small cetaceans was possible. It noted, however, that blast fishing was known to occur in the Solomon Islands and elsewhere in the Pacific Islands Region. There must be at least locally reduced water quality around Honiara. The long-term provisioning of dolphins in sea pens is likely to lead to local deterioration of the surrounding marine environment. Clear-felling of forests has affected reef quality in other parts of the Pacific and this might also be true in the Solomon Islands. Similarly, mining activities occur in the Solomon Islands and some of these might contribute to habitat degradation. Finally, there are many submerged vessels

from World War II in the sea around the Solomon Islands, and these pose some risk of toxic leakage or spills, especially of fuel.

5.4 Noise

No information on underwater noise around the Solomon Islands was available to the workshop. It was simply noted that marine tourism involving fishing and diving takes place around Honiara, and this would be one source of underwater noise that could affect dolphins.

6. Units to conserve

Deciding on units to conserve is a fundamental aspect of assessment (Taylor 2005). It is widely understood as a central tenet of conservation biology that, especially for wide-ranging species such as most cetaceans, conservation at the species level alone is inadequate. This principle is recognized by the IUCN Red List, which encompasses assessment of subspecies and geographical populations (“subpopulations”) as well as species, and by the IWC, which has since the 1970s managed whaling with a focus on whale populations rather than species. Also, the CITES definition of “species” refers to “any species, subspecies or geographically separate population thereof.”

Units to conserve are defined in different ways according to the context, but multiple lines of evidence for understanding population structure can be used – e.g. genetics, range disjunction, morphology and morphometrics, social and behavioural patterns, colour patterns, or physical barriers to movement. For the most part, these lines of evidence are used as proxies for establishing that there is a complete or nearly complete lack of demographic interaction between populations. In situations where no evidence is available or the available evidence is inadequate or inconclusive, one default approach (pending collection of suitable data) is to use what is known about the species (or a closely related species) in other locations to infer likely scenarios of population structure in the area of interest. An alternative default would be to recognize the animals in an area where exploitation occurs as a (management) stock (Dizon and Perrin 1997, p. 11). However, this approach may not be risk-averse in all situations (e.g. when the animals migrate or experience mortality in several fisheries in different areas or seasons) and therefore it is essential to obtain information on dispersal and migration as quickly as possible.

The workshop raised a number of issues that should be considered in determining units to conserve. These issues are simply flagged here, without comment. They are followed by summaries of workshop presentations and discussions of genetics and radio-tracking – two of the main approaches for studying population structure in cetaceans.

- The lack of molecular genetic evidence of population structure should not necessarily lead to the conclusion that no structure exists. Before reaching such a conclusion, analyses with sufficient statistical power to detect differences are required. Moreover, in some circumstances other types of evidence are as informative as molecular genetic evidence, or even more appropriate for defining units to conserve. Some genetic markers suitable for analysis of phylogeography and longer-term evolution do not have the resolution necessary for delineating demographically independent populations.
- In considering island-associated populations of small cetaceans, it is important to examine movement patterns of individuals (e.g. through photo-identification, “genetic fingerprinting,” radio telemetry) and evaluate credible hypotheses for population isolation or inter-island mixing.

- Patterns of productivity should be examined to evaluate the likelihood that a population of dolphins would be restricted to near-shore or shelf waters as opposed to travelling offshore and widely.
- In assessing the potential impacts of a hunt (or other removal regime) that takes place in a restricted, relatively small area, it is important to consider the likely differences between populations that are structured over small spatial scales and those with little or no structure at the local scale. The finer the spatial scale of population structure, the greater should be the concern about potential for depletion or local extirpation.
- It is reasonable to assume, pending the availability of data showing otherwise, that the population structure of *T. aduncus* in the Solomon Islands is more like that of other localised, coastal species such as *Sousa chinensis* than it is to wider-ranging, offshore populations of species such as *T. truncatus* and *Stenella attenuata*.

6.1 *Tursiops genetics*

Common bottlenose dolphins (*T. truncatus*) occupy a wide range of coastal and oceanic habitats throughout tropical and temperate waters worldwide. In some regions, “inshore” and “offshore” forms or ecotypes differ genetically and morphologically, despite no obvious boundaries to interchange. Significant population structure over relatively small geographic distances have been documented in several coastal *T. truncatus* populations worldwide, such as those along the coasts of the Gulf of Mexico (Duffield and Wells 1991; Sellas *et al.* 2005), Bahamas (Parsons *et al.* 2006), Mediterranean and Black Seas (Natoli *et al.* 2005; Viaud-Martinez *et al.* 2008), New Zealand (Tezanos-Pinto *et al.* 2009), and south-eastern and western Australia (Bilgmann *et al.* 2007; Krützen *et al.* 2004). It must be noted that the populations studied in Australia included individuals of uncertain taxonomy (Möller *et al.* 2008; Krützen and Sherwin 2004). The significant genetic structure is consistent with the site fidelity and social organization described for *Tursiops* through long-term direct observations of recognized individual dolphins (Connor *et al.* 1992, 2000; Scott *et al.* 1990; Wells *et al.* 1987). The only areas studied to date where no significant population structure in bottlenose dolphins was found were in the North Atlantic off the Azores and Madeira (Quéroil *et al.* 2007). Dolphins in the Azores have extensive home ranges with long-distance movements that seem to be in response to low densities of prey; such movements would provide opportunities for interbreeding between neighboring localities and thus result in a lack of genetic differentiation (Silva *et al.* 2008).

A worldwide comparison of mitochondrial DNA control region sequences showed that all haplotype sequences for *T. truncatus* found in the Pacific, regardless of a population’s habitat use (i.e. coastal or oceanic), were more closely related to the “offshore” ecotype in the western North Atlantic than to “inshore” populations from the same region (Tezanos-Pinto *et al.* 2009). Analysis of gene flow indicated long-distance dispersal by coastal and oceanic populations worldwide, except for those haplotype sequences described as belonging to the “inshore” ecotype from the western North Atlantic. This result indicates that *T. truncatus* populations worldwide (except for the “inshore” ecotype in the western North Atlantic) are interconnected on an evolutionary timescale and it suggests that habitat specialization has occurred independently in different ocean basins. Furthermore, populations classified as belonging to the “inshore” ecotype from the western North Atlantic seem to be on an independent evolutionary trajectory representing a different taxon.

Preliminary genetic analyses were conducted with *Tursiops* samples collected in New Caledonia, including a comparison with sequences in a worldwide dataset of *T. truncatus* and *T. aduncus* from China, Taiwan, Indonesia, Australia and South Africa. Results confirmed the presence of both *T. aduncus* and *T. truncatus* in New Caledonia, with clear genetic differentiation that included several fixed diagnostic nucleotide sites and high divergence (Tezanos-Pinto *et al.*, in prep.). Additionally, the two species were found in different habitats, with *T. aduncus* occupying shallower waters (C.

Garrigue, pers. comm.). Analysis of genetic divergence suggested that *T. aduncus* from New Caledonia are more closely related to *T. aduncus* from mainland China, Taiwan (sequences published by Wang *et al.* 1999) and Indonesia than to animals with the sequence of the holotype specimen of *T. aduncus* from the Red Sea (Perrin *et al.* 2007; Tezanos-Pinto *et al.*, in prep.).

A working group of Tezanos-Pinto, Oremus and Wang met separately during the workshop and prepared the following summary of current understanding of *T. aduncus* genetics:

Taxonomy within the genus *Tursiops* remains controversial. Although two species are currently recognized, some issues remain unresolved (Reeves *et al.* 2004; Möller *et al.* 2008). The mitochondrial DNA (mtDNA) sequence of the holotype of *T. aduncus* (Perrin *et al.* 2007) matched a haplotype belonging to *Tursiops* specimens from coastal waters of southern Africa and seemed more closely related to *T. truncatus* than to *T. aduncus* of the western Pacific Ocean (Natoli *et al.* 2004; Tezanos-Pinto *et al.*, in prep). This suggests that the western Pacific *T. aduncus* represents a different taxon. Nevertheless, there is clear genetic differentiation between *T. truncatus* and *T. aduncus* in the Pacific region (Tezanos-Pinto *et al.*, in prep; Wang *et al.*, 1999). Genetic analyses have suggested significant population structure at relatively small geographic scales in populations of *Tursiops* sp. in South and Western Australia (Bilgmann *et al.* 2007; Möller *et al.* 2007; Krützen *et al.* 2004). Wherever *T. aduncus* populations have been studied, they exhibit restricted ranges/movements, strong philopatry, small population size and presumably low levels of genetic diversity (Kogi *et al.* 2004; Shirakihara *et al.* 2002; Stensland *et al.* 2006) and this is consistent with the biology of the species to the extent that it is known (Wang and Yang 2009). It also accords with what is known about inshore populations of other species of small cetaceans such as the Indo-Pacific humpback dolphin and contrasts with what is known about species that inhabit open oceanic waters. In the Indo-Pacific, *T. aduncus* may fill an ecological niche similar to that occupied by populations of what is called the inshore ecotype of *T. truncatus* in the western North Atlantic (Tezanos-Pinto *et al.* 2009).

The presumed *T. aduncus* from New Caledonia clearly aligns with the *T. aduncus* from China and Indonesia and is clearly different from *T. truncatus*. The supposed *T. aduncus* from the Solomon Islands is assumed to be genetically similar to that from New Caledonia although fine-scaled genetic structure over reasonably short distances has been reported for *Tursiops* sp. in Western and South Australia (Bilgmann *et al.*, 2007; Krützen *et al.*, 2004). It is obviously desirable for DNA samples to be obtained from the Solomon Islands (or from animals collected there but whose tissues should now be obtainable in either Mexico or the UAE) for comparison with samples from New Caledonia and other areas. Overall, studies to date have indicated that populations of *T. aduncus* tend to have lower genetic diversity than those of *T. truncatus*. This may be related to their inshore or near-shore distribution and their tendency to live in relatively small groups. If this tendency to have relatively low genetic diversity holds up, a detailed investigation of the species' evolutionary ecology will be needed to explain it.

6.2 Illustrative case study: spinner dolphins in French Polynesia

Oremus gave a brief presentation of his genetics research on insular spinner dolphins in French Polynesia, with potential lessons relevant to future work with *T. aduncus* in, e.g., the Solomon Islands. Gray's spinner dolphin (*Stenella longirostris longirostris*) occurs in apparently small, discrete populations around many of the Pacific islands. Spinner dolphins can live in a complex network of insular populations (metapopulation structure) where social and genetic boundaries are not easily predictable (Oremus *et al.* 2007). For instance, geographic distances have been shown to be a poor predictor of gene flow levels in the Society Archipelago (French Polynesia). Furthermore, levels of genetic diversity within island populations were found to be inconsistent with census population size. Combining demographic (photo-identification) and genetic approaches has proven to be valuable to

clarify the dynamics of insular populations over a 2-3 year study period. Such a relatively short-term study can produce results with important conservation implications.

6.3 Radio-tagging and tracking

Definition of population units can benefit from the application of a combination of approaches. Patterns of dolphin movements and habitat use can be evaluated from the locations of repeated sightings during photo-identification efforts. The accumulation of locations of individual animals can be accelerated through the attachment of radio transmitters and the use of direct or remote tracking (Wells *et al.* 1999, 2008, in press; Corkeron and Martin 2004). Direct radio-tracking works within a limited spatial scale of line-of-sight between the tracker and the animal, typically involving VHF signals, and occurs in real time. Remote tracking refers to the tracking of satellite-linked transmitters at any time of day and under all conditions, anywhere in the world, with an inherent delay of up to several hours for signal processing and data distribution from a receiving station. Attachment of transmitters to small cetaceans such as *T. aduncus* usually requires handling of the animal during brief capture and release, although some satellite transmitters are available that can be attached without capture. Collection or drive fishery operations may provide opportunities to tag and release dolphins determined to be commercially or otherwise undesirable after capture. Ideally, dolphins should be tagged with both VHF and satellite-linked transmitters, allowing tracking if the animals move outside the range of boat-based efforts but still improving ability to find groups for more intensive photo-identification and behavioural observation work while they are within range of research vessels. Currently available transmitters can be expected to function for up to several months.

7. Methods to estimate population size for small cetaceans

7.1 Overview

Interpretation of the abundance that is being estimated is usually straightforward with a line transect survey – it is the number of animals in the study area at the time of the survey. Interpreting what is being estimated in a mark-recapture study is more complex – it is the number of individuals that use the study area over the time period of the surveys. This might represent only the number of animals within the study area (if there is little movement into and out of it) or it might represent the entire population (if there is substantial movement by all individuals in the population into and out of the study area). The use of photo-identification for abundance estimation also has the potential to provide information on movements of individuals. The use of radio or satellite tracking combined with photo-identification data can in some cases be a way to obtain information on the range and movements of individuals quickly. There is conservation value in designing surveys so that they cover several different species, but it may not be easy or even feasible to balance survey effort between species that occupy different habitats, such as near-shore versus offshore waters.

Aerial surveys can be useful for determining the distribution of a species, and can be excellent for estimating abundance, but only if species identification from the air is reliable (there are major problems with identifying *T. aduncus* from the air). If aerial surveys are preferred, careful evaluation should be given to the selection of a proper aircraft and the safety standards of charter companies.

Boat-based photo-identification and/or line transect surveys can often be excellent for abundance estimation. Genetic identification may also be used for mark-recapture abundance estimation; it may help avoid biases inherent in photo-identification although it may bring its own different set of biases. Another consideration is that biopsy sampling may be more time-consuming and costly than photo-identification for mark-recapture abundance estimation, but this will be influenced by the target species and the working conditions.

7.2 Estimating abundance of *T. aduncus* in the Solomon Islands

Wade led a working group (with Baird, Defran, Wang and Wilson) to develop the specifications for an ideal approach to estimate abundance of *T. aduncus* in the Solomon Islands. The rest of this section constitutes the report from that group.

After considering a number of possible survey methods, it was concluded that small vessel surveys for photo-identification work, using mark-recapture analysis techniques, are preferred for estimating abundance of *T. aduncus* in the Solomon Islands. Other methods were judged non-ideal for various reasons. Airplane line-transect studies can provide estimates of abundance, but species identification of dolphins can be difficult from the air, and reliable differentiation between *T. aduncus* and *T. truncatus* from the air would be impossible in most circumstances at present. A line-transect survey from a vessel could also be used to estimate abundance, but was not considered to be the most efficient survey technique. For a similar amount of vessel time, a photo-identification survey would likely provide a more precise estimate of abundance, given the relatively low encounter rates seen in initial studies (e.g. ~ 1 encounter for every 3 days of survey effort along the northern coast of Guadalcanal) and the fact that group sizes are large enough to provide a substantial sample size for photo-identification work from relatively few encounters. Additionally, photo-identification studies will provide valuable data for investigating whether individual animals move between islands.

Ideally, surveys should cover all of the main islands. It may be necessary to conduct the overall survey in stages over time. As a first priority, it is recommended that an initial survey cover, at a minimum, the four main islands in the eastern portion of the Solomon Islands – Guadalcanal (including the Florida Islands), Malaita, San Cristobal and Santa Isabel. The rationale for identifying this area as a priority is that currently live-capture removals of *T. aduncus* are known to have occurred only off Guadalcanal, and Malaita, San Cristobal and Santa Isabel Islands all lie approximately similar distances from Guadalcanal and the Florida Islands and thus represent the most likely locations of emigrants or immigrants. It would be ideal to also survey around other smaller islands in the eastern Solomon Islands (e.g. the Russell Islands), but the majority of the potential habitat for *T. aduncus* presumably would be covered by a survey of the four major islands identified above.

A single field season, as defined here, would be expected to provide one sample for a mark-recapture abundance estimate. Ideally, four field seasons conducted over two years are recommended. Within each year, two field seasons should be conducted at least 3-4 months apart, to allow animals to redistribute themselves between samples, and also to allow sufficient time for movements between islands, if they occur. This will provide a total of four samples, with the potential to maximize detection of movements between islands and identify seasonal influxes of animals, if they occur. Ideally, the two field seasons within a year should be separated within the year to cover different seasonal conditions. If at all possible, the researchers should choose periods when weather conditions are ideal, although it is recognized this may be feasible for only one of the field seasons within a year. It is recommended that local knowledge and weather data be considered (e.g. NOAA weather data) to identify monthly mean wind patterns and good times of year for survey work.

During a field season, the survey at each island should be conducted in approximately the same way; it is not recommended to concentrate effort at one island within this study region. Without prior knowledge of the density of animals at each island, it is impossible to predetermine an ideal survey effort for each island. On each of the four islands, a balance will need to be struck between maximizing encounters with *T. aduncus* and conducting complete surveys around islands. It is strongly recommended that attempts be made to obtain identification photographs of animals from all around each island in the study area. This is necessary to give all individuals an opportunity to be

sampled, while attempting to obtain an adequate sample size of identified individuals from each island. It is recognized that any field effort will experience different conditions around a given island, depending upon the prevailing winds, and will often have to deal with windward and leeward conditions that make it especially difficult to accomplish survey effort on the exposed windward side of the island. Therefore, it is understood that survey effort does not have to be equal throughout each island, but opportunities should be sought for accomplishing survey effort on windward sides. Without being too prescriptive, a possible plan would be to attempt to survey the windward side of each island at least twice, and leeward areas could be surveyed as many times as possible while waiting for weather conditions that would allow survey effort along windward coasts. If weather conditions constrain work during part of the survey to a single area, daily survey patterns should attempt to maximize coverage within that area by, for example, a pattern of going in one direction one day and another direction the next day.

Throughout their range, *T. aduncus* have been found to occupy shallow and near-shore waters primarily. Initial studies in the Solomon Islands (by Defran) have found this to be true there as well. Therefore, it is recommended that the study area at each island be defined as all waters within the 200 m depth contour, with the adjustment that when that contour is very close to shore, the study area should be expanded out to at least 2 km from shore. Stated another way, the outer boundary of the study area should be 2 km or the 200 m depth contour, whichever is farther from shore. Such a survey design should maximize encounters with *T. aduncus*. Obviously, while conducting the surveys, any group of *T. aduncus* sighted, regardless of distance from shore or depth, should be approached and photographed. However, the available data give no basis for believing that it would be efficient to spend substantial time surveying deep waters. It is recognized that some shoal areas could be difficult to enter and the daily survey effort may have to adjust for that. Within this overall design, it is perfectly acceptable to adjust the survey for local conditions and knowledge to attempt to maximize the detection of groups of *T. aduncus*.

Although data from throughout the range of *T. aduncus* (including the Solomon Islands) indicate that sightings in deep water are rare, it is still important to confirm this for all areas. Therefore, it is recommended that some offshore lines between islands be surveyed. This could be accomplished during movement of the vessel from one island to another, while searching should continue in the same manner as during transects around islands (assuming the vessel is large enough to make this practical).

The type of survey vessel to use may differ depending upon different logistics at each island. Close approaches for photo-identification can be accomplished either from small boats (skiffs such as inflatables or ~20-26 foot sport-fishing boats) or from a larger boat such as a small live-aboard. The use of a small or medium-sized live-aboard may be the most logistically feasible way to complete the survey of all islands, given the constraint that small boats can operate only out of suitable ports. If the live-aboard is too large to easily navigate the shallow waters of the survey area, it may be necessary to work from a skiff (such as an inflatable) launched from the live-aboard.

When working from small boats, it is helpful to use a raised platform to increase eye height. Experience has shown that even 0.3-1.0 m of extra elevation above sea level can help. Survey speed can vary over a reasonable range. In good conditions, a speed of 10-15 knots works well, but speed can be adjusted to meet survey conditions. It is usually necessary to slow down in rough conditions.

Experience in the Solomon Islands suggests that *T. aduncus* are relatively easy to detect given their behaviour of surfacing synchronously, yielding a larger target for detection. However, experience in places like Sarasota and Hawaii suggests that detection probability for small to medium-sized groups of dolphins from small boats falls off rapidly beyond ~100-400 m. Therefore, to ensure complete

coverage of the study area, the vessel should follow a path to cover all areas from close to shore to the outer limit of the study area. This could be accomplished with a zigzag type of pattern if this is logistically efficient, but survey effort for a photo-identification study does not need to follow a specific, pre-determined trackline. When repeating sections of the study area, consideration should be given to adjusting surveys on each day to minimize the overlap of trackline effort from day to day, and to maximize the spatial extent of coverage of the study area.

Experience has shown that at least two observers are needed and, if space allows, as many as 4-6 observers have been used on similar surveys. At least two people with previous experience with small cetaceans in the tropical Pacific should be involved in the study. Obviously, it is beneficial to use observers with good visual abilities. It is recommended that observers scan 360 degrees around the vessel while on effort. In some similar studies it has been found that occasional scanning with binoculars can be beneficial for the detection of dolphin groups. For photo-identification, it has often been found to be good to have at least two experienced photographers to maximize collection of photographs during ideal moments and as a form of backup, but it is important for multiple photographers to coordinate their shooting to ensure that all individual dolphins in a group are photographed. Given that it is unproductive to survey for *T. aduncus* in sea-surface conditions of Beaufort 3 or worse, it is recommended survey effort be adjusted so that work is conducted in areas with sea states lower than Beaufort 3. However, there is no reason to stop photographic effort if conditions worsen during an encounter.

It is recommended that attempts be made to photograph every individual's left and right sides, understanding that this may not always be feasible. Individual *T. aduncus* are identified primarily by reference to nicks in the dorsal fin, so identification and matching should be reliable from photographs of either side.

It is recommended to spend enough time with groups to photograph all individuals without bias towards marked individuals. This will allow estimation of the percentage of marked individuals in a population, to be used for correction of abundance estimates of marked individuals. It is useful to continue to scan for other groups while conducting close approaches for photographs in order not to miss opportunities to "mark" or "capture" more animals.

Besides photographs, data that should be collected include trackline data (as recorded on a GPS) for all survey effort, along with the locations of encounters and the times and locations when search effort is stopped and resumed. The group size should be estimated at each encounter; this is typically done by estimating best, minimum, and maximum. Additionally, Beaufort sea state should be recorded with effort. When dolphins are encountered, the water depth should be recorded from a depth sounder if available.

Although the design of the survey would be focused specifically on estimating abundance, given the amount of time and resources required to conduct these studies, the working group gave some consideration to what other data should be collected.

It is recommended that biopsy samples be collected, when possible, for genetic studies of population structure and genetic diversity (see 9.2, below). With a large enough sample size, genetic identifications can be used to produce a separate mark-recapture abundance estimate.

It is also recommended that observers record information on stage and sex composition, such as observations of cow/calf pairs, and on occurrence of neonatal animals. Information on neonates (very small calves exhibiting foetal folds) in particular can be valuable for identifying the seasonal timing of reproduction.

The survey team should collect sighting information on other species, but considerable time should not be spent on photo-identification of other species, given that this could prevent the team from accomplishing its primary mission. It is suggested that only a brief period of time be spent taking photographs of other species, unless resources allow time for this activity in addition to collecting sufficient data on *T. aduncus*. If photographic effort on other species is possible, it is recommended that time devoted to other species be spent in inverse relationship to their encounter rate – data from the species most rarely encountered can often be the most valuable.

It is important to recognize that once the photographs have been collected, considerable work remains before an abundance estimate can be produced from the photo-identification data. It is recommended that the data be entered into a database programme (e.g. such as Access). Previous photo-identification studies of dolphins have developed rigorous methods for photo-quality grading and mark type/distinctiveness grading (e.g. Read *et al.* 2003). These are essential steps that must be taken before an abundance estimate is made, and it is recommended that sufficient time and human resources be included in the research planning and design to ensure that a rigorous, credible end-product is achieved. Finally, it is not possible here to describe in detail the analysis that should be undertaken for abundance estimation. The choice of model or models (e.g. use of both open and closed models, for comparison) should be left to the researcher, based on his or her experience with the animals, the data collected, etc. Mark-recapture software such as the programme MARK can be used to estimate abundance from the survey data.

8. Assessment algorithms

Several approaches are available for assessing the potential impacts of removals from dolphin populations. For large populations, the PBR approach (as described above in Section 2) can guide management of removals relative to maintaining the maximum productivity of populations. As populations decline to levels where extirpation or extinction is an immediate possibility, population viability analysis can be used to simulate population dynamics under different harvest and management scenarios (Beissinger and Westphal 1998). However, it is important to bear in mind that managing populations relative to extirpation or extinction is a much more risky strategy than managing them at precautionary productivity levels relative to sustainability.

8.1 Population Viability Analysis (PVA)

VORTEX 9.91 (Lacy 2000a; Lacy *et al.* 2008) has been used to simulate population dynamics for common bottlenose dolphins and to perform extrapolations for hypothetical situations involving removals. VORTEX is an individual-based simulation model that incorporates mean demographic rates, the randomness of individual demographic events (demographic stochasticity), annual variation in rates (environmental variation), any catastrophic events, emigration and immigration, habitat carrying capacity limitations, and harvest or supplementation of populations into projections of population size, predictability or fluctuations in size, probabilities of persistence, and genetic variation. VORTEX produces estimates of mean deterministic population growth (R_{max}) from the average life table rates and the mean population growth expressed in the stochastic simulation model that also incorporates the many sources of variation in demographic performance (Lacy 2000b). In an exploratory analysis prepared for this workshop, Wells and Lacy used 500 iterations of the stochastic simulation to project a population viability for each scenario described by a set of demographic rates or levels of take from the population. Each scenario was simulated for 100 years. Although this is longer than any likely management or conservation plan, the extrapolation of the current population dynamics over a long duration makes it easier to see the effects of management actions, especially when these involve animals with long life spans.

Input parameters for VORTEX included information on *T. aduncus* as available (summarized in Wang and Yang, 2009; and see Table 2). When data specific to *T. aduncus* were not available, data from long-term studies of common bottlenose dolphins in Sarasota Bay, Florida, were used (Scott *et al.* 1990; Wells and Scott 1990; Wells 1991, 2003). Sarasota Bay data are consistent with data reported from other sites for *T. truncatus* (Wells and Scott 1999). Where data are available for both species, most demographic and life history parameters are similar (Wells and Scott 1999, 2002; Wang and Yang 2009), with the exception of age at first reproduction of females. In a review and comparison of *Tursiops* populations worldwide, Connor *et al.* (2000) did not document any births to *T. aduncus* younger than 12 years old. Age-specific fecundity and mortality data from Sarasota Bay dolphins averaged over 1993-2007 were used in VORTEX simulations (Table 3). Expected random variation (“demographic stochasticity” or intrinsic sampling variation) has been factored out of the observed standard deviations of rates across years to produce estimates of the environmental variation in each demographic rate. The deterministic projections of VORTEX assume no stochastic fluctuations, no inbreeding depression, no limitation of mates, no harvest, and no supplementation. The stochastic simulations by VORTEX then add in these factors to determine the average impacts and the variation or uncertainty in the population performance.

Table 3. VORTEX input values for fecundity and mortality.

<u>Parameter</u>	<u>Mean</u>	<u>Environmental Variation (S.D.)</u>
Mean fecundity (births/adult female/year)	0.208	0.085
Mean mortality (first year)	0.247	0.098
Mean mortality (later ages, all sources)	0.027	0.012

Incorporating age-specific rates of mortality and fecundity (Table 3), the VORTEX model yields an estimated potential deterministic population growth rate for Sarasota Bay dolphins of 2.8% per year when documented cases of human-induced mortality are removed (2.4% with human-induced mortality). When mortality rates as observed in Sarasota Bay were combined with the later onset of breeding (12 years) observed for female Indo-Pacific bottlenose dolphins in Shark Bay, Western Australia (Connor *et al.* 2000), the projected mean rate of increase was 1.6% per year.

Input data specific to the Solomon Islands are lacking for VORTEX estimation of sustainable removals. No published data are available on the abundance, potential population growth rate, stock structure, or demographics of bottlenose dolphins in the Solomon Islands. However, some information is available on dolphins collected from the waters around the islands, providing a basis for estimating harvest rates for simulations that can extrapolate to the population sizes necessary to support the harvest. The Marine Mammal Education Centre (SIMMEC) in the Solomon Islands provided sex and estimated age data for 47 dolphins in its collection in 2003 (wild-caught: 12 females (7 adult) and 34 males, plus 1 captive-born female neonate) (Ross *et al.* 2003). Three annual live-capture removal scenarios were applied: (1) 6F:6M, (2) 12F:12M and (3) 24F:24M. VORTEX performed 100-year population projections, using Sarasota Bay dolphin parameters for mortality (omitting human-induced mortality), the estimated potential rate of population increase of 1.6% per year, and the later onset of breeding (12 years) observed in the Indian Ocean, and varying initial population sizes from 500 to 4,000 dolphins.

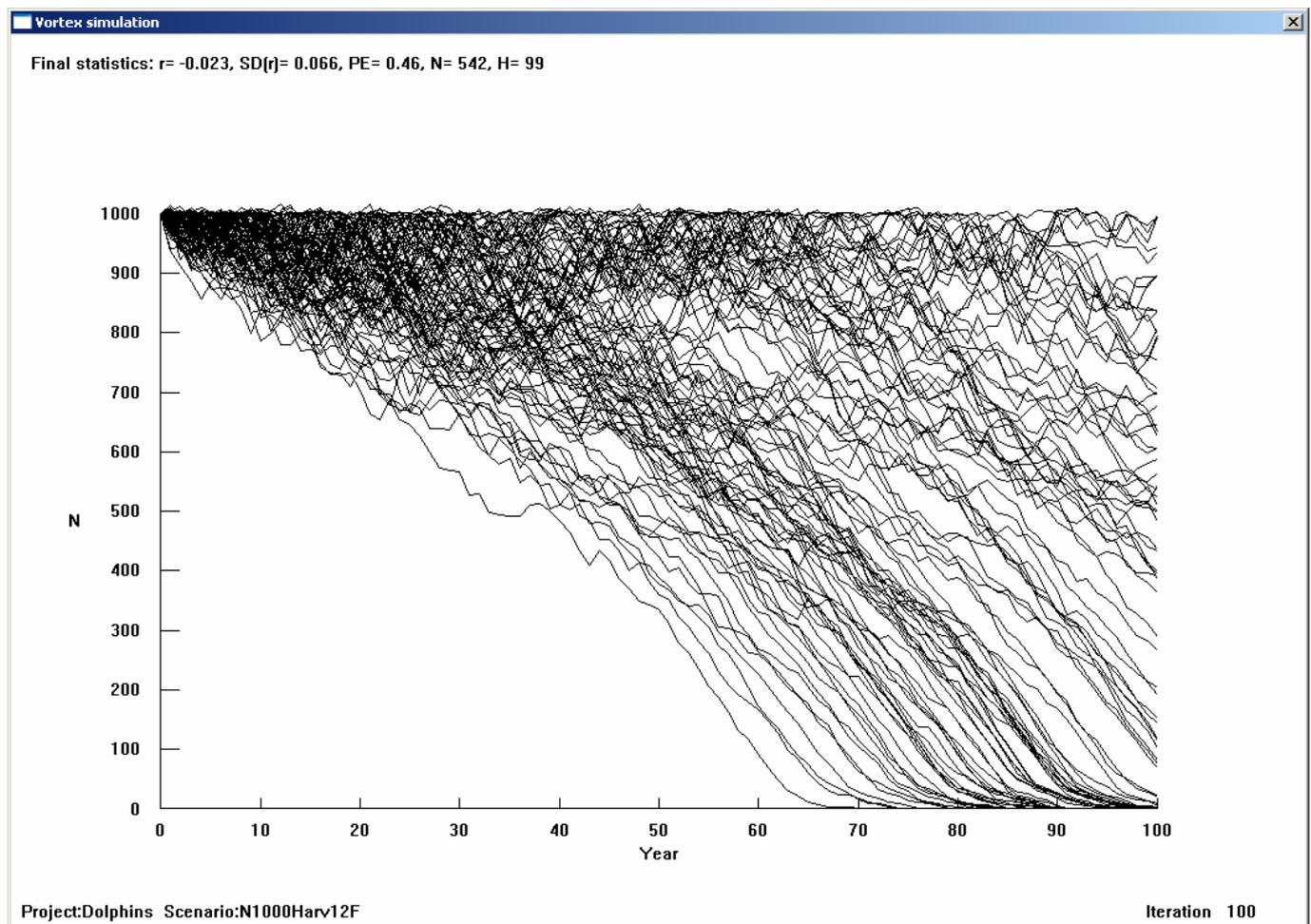
Within each of the removal scenarios, relatively high probabilities of extinction resulted from the first two initial population size options, and large reductions in population size occurred with the first three of four initial population size options within 100 years (Table 4).

Table 4. Results of VORTEX simulations exploring varying initial population sizes and harvest rates over 100 years.

<u>Adult mortality</u>	<u>Annual harvest rate</u>	<u>Initial N</u>	<u>Carrying Capacity (K)</u>	<u>Label</u>	<u>Projected mean pop. growth</u>	<u>Mean pop. growth in simulation</u>	<u>SD(r) across years</u>	<u>Prob. extinction in 100 y</u>	<u>Mean N at y100 if not extinct</u>	<u>SD(N) across years</u>	<u>Mean N across extant and extinct simulations</u>	<u>SD(N) across years for extant and extinct</u>
				<u>Scenario</u>	<u>det-r</u>	<u>stoc-r</u>	<u>SD(r)</u>	<u>PE</u>	<u>N-extant</u>	<u>SD (Next)</u>	<u>N-all</u>	<u>SD(Nall)</u>
2.7	6 F & 6M	500	500	N500Harv6F	0.016	-0.043	0.07	0.854	58	67.87	10.12	32.58
2.7	6 F & 6M	625	625	N625Harv6F	0.016	-0.025	0.05	0.234	134	123.41	103.89	120.96
2.7	6 F & 6M	750	750	N750Harv6F	0.016	-0.008	0.031	0.01	368	186.87	364.77	189.37
2.7	6 F & 6M	1000	1000	N1000Harv6F	0.016	0.002	0.026	0	845	152.8	845.04	152.8
2.7	12F & 12 M	1000	1000	N1000Harv12F	0.016	-0.047	0.071	0.904	67	58.02	8.74	26.43
2.7	12F & 12 M	1250	1250	N1250Harv12F	0.016	-0.027	0.053	0.262	234	214.77	174.59	209.87
2.7	12F & 12 M	1500	1500	N1500Harv12F	0.016	-0.009	0.031	0.014	705	365.34	695.71	371.89
2.7	12F & 12 M	2000	2000	N2000Harv12F	0.016	0.001	0.026	0	1687	297.22	1686.59	297.22
2.7	24F & 24M	2000	2000	N2000Harv24F	0.016	-0.05	0.072	0.944	98	100.85	8.37	32.54
2.7	24F & 24M	2500	2500	N2500Harv24F	0.016	-0.028	0.051	0.24	453	437.92	347.59	425.68
2.7	24F & 24M	3000	3000	N3000Harv24F	0.016	-0.01	0.031	0.008	1320	720.96	1309.18	727.49
2.7	24F & 24M	4000	4000	N4000Harv24F	0.016	0.001	0.025	0	3372	620.5	3372.37	620.5

Overall, if a fixed number of dolphins is removed from a population each year (as might happen in a capture for exhibition trade), then it seems that the population needs to be about 50 times larger than the removal level to maintain zero mean population growth (i.e. removal rates of about 2% set it back to zero or negative population growth). However, even when the rate of removals is slightly less than the expected mean rate of population growth, the model still predicts some extirpations/extinctions because after any years of poor breeding or survival, the (then unsustainable) live-capture removals push the population into a downward spiral. This is exemplified in Figure 2, showing a case with a removal rate that starts at 2.4% of initial population size but then the population crashes after a few bad years (i.e. years with, perhaps by chance, naturally poor reproductive output or survival), reaching levels that are unable to sustain that scale of removals annually. Population size for a dolphin population with demographics typical of those seen for Sarasota Bay *T. truncatus* would need to be about 60 to 65 times larger than the removal level to assure that the taking does not cause any population crashes.

Figure 2. VORTEX simulation for a population of 1,000 bottlenose dolphins, with an initial population growth rate of 2.4%, comparable to Sarasota Bay dolphins with current rates of human interaction plus a removal rate of 12 females/ year. Most scenarios among the 100 iterations resulted in population decline, with an average potential population growth rate of -0.023.



In workshop discussions, it was noted that, given the assumed input parameters from the Sarasota dolphins, annual live-capture removals of > 2.5% would be expected to result in population decline. Given instead the inferred input parameters for Indo-Pacific bottlenose dolphins, annual removals of > 1.5% would lead to decline. Therefore, a useful rule of thumb for maintaining population size (without provision for stochastic events) would be that the population needs to be at least 67 times the size of the annual removal. Allowing for stochastic events, it should be even larger.

Several issues were raised concerning the application of PVA. For one, the typical forward-looking timeframe of ~100 years is not necessarily sufficient for all individuals in a population of long-lived animals to die. Therefore, PVA could under-represent extinction risk for that population. For another, the number of individuals taken by directed capture efforts may not be proportional to the total population size. The uncoupling of abundance and take rate might result in positively biased estimates of extinction risk if, for example, dolphins learn to avoid hunters and become more difficult to herd or entrap (although this assumes that there is no elasticity of hunting effort). At the same time, if hunters can continue to find dolphins even at low levels of abundance (because the dolphins occur reliably or predictably in preferred locations), then the extinction risk would be greater than what was estimated by assuming a proportional take. Finally, PVA generally does not incorporate consideration of the social consequences of selective removals (nor does PBR), such as those made for captive display (which tend to emphasise young females).

There is an important distinction between a PVA, which seeks to characterise the risk of extirpation/ extinction, versus a PBR analysis, which is normally used to help prevent the depletion of a relatively large population. Reductions of small populations potentially differ from proportionally similar reductions of larger ones because of the Allee effect, or depensation, which refers to situations where populations of only a few individuals (e.g. typically 20-50) are unable to increase because of such things as an inability to find a mate or the deleterious effects of inbreeding (see MMC 2007, p. 2, note 1). The number of animals required for so-called quasi-extinction depends on the biology of the species of concern, but the IUCN Red List criteria use 50 mature individuals as the threshold level for designating a population as Critically Endangered.

9. Synthesis

9.1 Research and assessment plan for island-associated populations of Indo-Pacific bottlenose dolphins

The following outline of items to include may serve as a template for assessment of an island-associated population of small cetaceans. Although Indo-Pacific bottlenose dolphins in the Solomon Islands served as a good “case study” at the workshop, the outline is intended to be equally applicable to other species and populations. It is an expansion of the statements from Reeves *et al.* (2003) cited earlier in this report (Section 1.1).

I. Definition and geographic boundaries of population (unit to conserve)

- a. Ecological and oceanographic considerations
- b. Gaps in distribution or low-density areas
- c. Movement or site fidelity using photo-identification, genetics and radio-tracking data
- d. Habitat use

II. Current estimate of abundance, with associated uncertainty

Obtained from either a line-transect survey or a mark-recapture analysis (requiring a minimum of at least two appropriately designed sampling episodes for the latter technique)

III. Selection of a value for maximum population growth rate

Given the lack of complete life-history data for *T. aduncus*, it is appropriate to use a default value for the maximum population growth rate (R_{max}). A value of 0.04 is appropriate for odontocete populations, has substantial precedence of use in many regions, and is deemed reasonable given what is known about the

life history of *T. aduncus*. However, it must be noted that observed rates of population growth for other dolphin species have generally been under 0.03 (e.g. killer whales, common bottlenose dolphins), which suggests that a lower value might be a precautionary default.

IV. Understanding of human-caused mortality

- a. Determine whether there has been, or is, non-deliberate mortality (e.g. bycatch, vessel strikes) and if so, estimate levels of such mortality
- b. Review and incorporate consideration of recent “historical” or ongoing deliberate removals (e.g. by hunting, live-capture)

V. Final assessment regarding potential impact on population from human-caused mortality

VI. Analysis of the data and information listed above using one or a combination of the following:

- a. IWC approach (at a minimum)
Takes of > 2% of the population size are unacceptable and cause for an immediate reduction, and takes of > 1% are cause for concern and signal the immediate need for research to assess the status of the stock.
- b. Potential Biological Removal (PBR) or similar methods
A range of values (0.6 to 1.8%) represents unacceptable take levels, depending on the specific method, the exact conservation objective and the precision of the abundance estimate. For a small population at risk of extinction, lower thresholds (0.1 to 0.9%) would be considered more appropriate. All of these values are broadly consistent with, but lower than, those used in the IWC approach.
- c. Population Viability Analysis (PVA)
For a small population at risk of extinction/extirpation, a case-specific PVA should also be conducted to supplement the above assessment methods.

VII. Follow-up monitoring and periodic reassessment to track population trajectory

For example, in the United States new abundance estimates are required at least once every eight years for management purposes.

9.2 Genetic sampling and analyses

Genetic tools have come to play a central role in many conservation studies. Access to genetic material and DNA analyses can contribute to assessments of the sustainability of removals from cetacean populations. The recent live-capture removals of Indo-Pacific bottlenose dolphins in the Solomon Islands are used here as a case study for both practical and illustrative purposes. This brief summary identifies sources of genetic material that could be used as well as the main conservation issues that can or should be addressed using genetic analyses. The conservation issues have been classified as ***Necessary*** or ***Desirable***.

1) Potential sources of genetic material:

1a) Samples from live-captured dolphins:

- Solomon Islands
- Mexico, UAE, Philippines

1b) Biopsy sampling obtained from boat surveys in the Solomon Islands

1c) Samples of *Tursiops* sp. from other regions (e.g. Genbank, collaborations)

1d) Samples of *T. aduncus* from the Solomon Islands in museums (e.g. National Museum of Nature and Science, Shinjuku-ku, Tokyo, Japan).

2) Conservation genetic issues:

[Note: For each issue listed below, we have indicated in brackets the potential sources of genetic material (from the above list) required to address the specific question.]

2a) What is the level of genetic diversity in the population(s) of *T. aduncus* in the Solomon Islands? Small, isolated populations are more prone to genetic depletion leading to inbreeding and increased risk of extinction. Given the level of exploitation in the Solomon Islands, estimation of the level of genetic diversity is imperative to provide appropriate management strategies. (1a+1b). **Necessary**

2b) Are there different stocks of *T. aduncus* in the Solomon Islands? The population structure should be assessed to identify evolutionarily significant units (ESUs), management units (MUs) or demographically independent populations (DIPs) and to estimate recent migration rates between populations. Genetic analyses could provide information that is complementary to that obtained from photo-identification studies and that is needed to define social and genetic boundaries of the population(s). (1a+1b). **Necessary**

2c) How do *T. aduncus* in the Solomon Islands relate to other *Tursiops* populations worldwide? The animals live-captured and exported from the Solomon Islands are assumed to be *T. aduncus*. However, current taxonomy of *Tursiops* is still controversial. Genetic studies should be conducted to clarify species status of the Solomon Islands population(s) and determine the level of genetic isolation from neighbouring populations in, for example, New Caledonia, Papua New Guinea, Indonesia, Vanuatu and Australia. (1a+1c). **Desirable**

9.3 *Cultural and other local considerations for researchers*

The Pacific Islands Regional Marine Species Programme 2008-2012 (SPREP 2007) consists of action plans, which list priority actions for the conservation of three groups of marine organisms in the region – whales and dolphins, marine turtles, and the dugong. The programme has been endorsed by all member nations of SPREP to accomplish an overall vision of conservation and management of regional marine resources. Within the programme, the need to increase local capacity and scientific understanding of local resources is noted repeatedly. In addition, it calls upon donors and supporters to assist in “implementing the action Plan at regional and national levels.”

The workshop acknowledged the importance of including regional considerations in the planning and conduct of cetacean research in the Pacific Islands, where cetacean science is in its infancy. Paying attention to such considerations is certain to lead to smoother, more effective implementation of research plans and help researchers avoid obstacles that could be encountered when trying to work in a given country or territory.

The following summary (developed by a working group led by Miller and including Bell, Garrigue, Horokou and Ward) represents a general approach to planning. It does not necessarily reflect the considerations needed for specific research activities, nor does it account for local circumstances (although it was prepared with the Solomon Islands in mind).

9.3.1 Prior to research

- An initial expression of interest should be given to relevant government ministries. This point of contact will allow the given ministry to provide feedback on the proposed work. Specific

comments may be given on the applicability of such work to relevant national and regional priorities and plans (e.g. SPREP 2007) and provide a conduit to appropriate intergovernmental organizations (such as SPREP, SPC and CMS) that could be integrated into such work. It is possible that comments from the government will include recommendations on how technical skill instruction and training opportunities can and should be incorporated into the research programme.

- It is preferable that the government be considered an active participant in the research plan and team, particularly to further in-country capacity building efforts. It is likely that an in-country government counterpart will be assigned to the project. This counterpart will facilitate national communications and organization of the research. Information and assistance from the counterpart may include investigating the use and availability of an appropriate research vessel, establishing communication with relevant villages, providing contacts in areas where research is proposed, and building appropriate timeframes into the research plan (e.g. travel times, weekly schedule, visits and meeting requirements). For the counterpart to be engaged in this planning process, it will be necessary to discuss the budget associated with the time and effort involved in carrying out these duties, both prior to the research and while it is being undertaken.
- Budget considerations should also be made for necessary maritime access and cultural ceremonies in certain parts of the proposed study area.
- Once a full application has been submitted, a governmental permit is required for research to proceed.
- It may be useful for a researcher to visit the country prior to undertaking fieldwork to confirm vessel suitability and become fully aware of research conditions.

9.3.2 During research

- The in-country government counterpart will actively facilitate access to communities or villages, provide guidance to researchers on cultural norms (e.g. attire, respectful communications and behaviour) and participate in research (if agreed).
- It is preferable for researchers to advise (and preferably visit) ministry staff when they are entering and departing the country.
- The project should be presented locally, at least informally, at the start and completion of the work.
- Informal updates to government departments and the in-country government counterpart are important and may be required throughout the course of the research.
- The in-country government counterpart should be debriefed at the end of the project to assist the research team in fulfilling its reporting requirements to relevant government ministries.

9.3.3 At the completion of research

- A final report of the research must be submitted to the relevant government ministry (likely a condition of the permit).
- It is preferable that reporting requirements include recommendations for future work and monitoring and management considerations. In addition, it is useful if the immediate application and relevance of such work is outlined.
- All in-country staff, assistants and contacts must be acknowledged for their activities and support in all reports and publications. Authorship should be given where appropriate.

10. Conclusions

There is a need to determine the conservation status of Indo-Pacific bottlenose dolphin populations, or populations of any inshore small cetacean, around any island where human-caused mortality or removal (direct or incidental catch) is known to be occurring. The Indo-Pacific bottlenose dolphin has a limited

coastal range throughout much of the Indo-Pacific Ocean except in areas with wide continental shelves. Their near-shore distribution makes these dolphins particularly vulnerable to exploitation and other anthropogenic threats. In some regions where the species has been studied, the populations of *T. aduncus* are small compared to open-ocean populations of common bottlenose dolphins (or other dolphin species) in adjacent offshore waters. For example, two well studied populations of *T. aduncus* in Japanese waters off western Kyushu and Mikura Island number only about 200 and 170 dolphins, respectively. The only known large concentrations (around 1,000 or more) are in regions with large shallow-water areas, e.g. Shark Bay on the western coast of Australia, North Stradbroke Island on the eastern coast of Australia, and the western Arabian Gulf. Populations of *T. aduncus* in the South Pacific islands are likely to be small, i.e. in the low hundreds, given the restricted areas of potentially suitable habitat around most of the islands.

The government of the Solomon Islands has issued a permit for the export of up to 80 dolphins (all *T. aduncus*) per year (CITES Secretariat document AC 23 Doc.8.5) and the present workshop learned that the annual allowable export level was being increased to 100 dolphins of any species, but most likely to be *T. aduncus*. If an international standard rule of 1%-2% (per IWC, ASCOBANS etc.; see Section 2.2) were applied in this instance, the local *T. aduncus* population used as the source of animals for export from the Solomon Islands would have to be at least 5,000 to 10,000 to sustain the permitted level of exports.

Based on the current state of knowledge of Indo-Pacific bottlenose dolphins throughout their range, as well as the information on this species in the Solomon Islands reviewed at the workshop, it appears that abundance in the area of recent live-captures is well below 5,000. Therefore, population assessment efforts in this region should be expanded as soon as possible. Based on workshop discussions, it was concluded that the best methods to assess abundance and delineate populations would be a combination of mark-recapture analyses of photo-identification data and genetic analyses. It is assumed that *T. aduncus* are not involved in the drive fisheries described by Takekawa (1996a) but if they are, then both types of removal need to be considered in any population status assessments.

11. References cited

- Acevedo-Gutierrez, A. 1999. Aerial behavior is not a social facilitator in bottlenose dolphins hunting in small groups. *Journal of Mammalogy* 80:768-776.
- Akimichi, T. 1991. Sea tenure and its transformation in the Lau of North Malaita, Solomon Islands. *South Pacific Study* 12(1):7-22.
- Akimichi, T. 1992. The surviving whale-tooth culture significances of whale products in Oceania. *Bulletin of the National Museum of Ethnology* 17(1):121-142.
- Angliss, R. P., and R. B. Outlaw. 2008. Alaska marine mammal stock assessments, 2007. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-180, 252 p. (<http://www.nmfs.noaa.gov/pr/pdfs/sars/ak2007.pdf>).
- ASCOBANS. 2000. Resolution No. 3 Incidental Take of Small Cetaceans, 3rd Session of the Meeting of Parties to ASCOBANS, Bristol, United Kingdom, 26 – 28 July 2000 (http://www.service-board.de/ascobans_neu/files/2000-6.pdf).
- ASCOBANS. 2006a. Resolution No. 5 Incidental Take of Small Cetaceans, 5th Session of the Meeting of Parties to ASCOBANS, The Netherlands, 18-20 September and 12 December (http://www.service-board.de/ascobans_neu/files/mop5-final-5.pdf).
- ASCOBANS. 2006b. Recovery Plan for Harbour Porpoises (*Phocoena phocoena*) in the North Sea and Background Document. ASCOBANS 13th Advisory Committee Meeting Document AC13/Doc. 18(S), Tampere, Finland, 25–27 April 2006 (http://www.service-board.de/ascobans_neu/files/ac13-18.pdf).
- Baird, R.W., Gorgone, A.M., McSweeney, Y, D.J., Ligon, A.D., Deakos, M.H., Webster, D.L., Schorr, G.S., Martien, K.K., Salden, D.R. and Mahaffy, S.D. In press. Population structure of island-associated dolphins: evidence from photo-identification of common bottlenose dolphins (*Tursiops truncatus*) in the main Hawaiian Islands. *Marine Mammal Science*.
- Beissinger, S.R. and M.I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. *Journal of Wildlife Management* 62:821-841.
- Best, P.B. 2007. Whales and dolphins of the southern African subregion. Cambridge University Press, Cambridge, UK.
- Bilgmann, K., Möller, L.M., Harcourt, A.H., Gibbs, S. and Beheregaray, L.B. 2007. Genetic differentiation in bottlenose dolphins from South Australia: association with local oceanography and coastal geography. *Marine Ecology Progress Series* 341:254-276.
- Brownell, R.L., Jr. and Reeves, R.R. 2008. Biological background on bottlenose dolphins (*Tursiops* spp.) in the "live-capture" trade and specifically on the Indo-Pacific bottlenose dolphin, *T. aduncus*. CITES Animals Committee, 23rd Meeting, Geneva, 19-24 April 2008, Document AC23 Inf. 5, 10 pp.
- Carretta, J.V., Forney, K.A., Lowry, M.S., Barlow, J., Baker, J., Hanson, B. and Muto, M.M. 2007. U.S. Pacific Marine Mammal Stock Assessments: 2007. US Department of Commerce, NOAA Technical Memorandum, NMFS-SWFSC-414. 320 p. <http://www.nmfs.noaa.gov/pr/pdfs/sars/po2007.pdf>

- Chapman, L. 2001. Bycatch in the tuna longline fishery (working paper 5). 2nd South Pacific Commission Heads of Fisheries Meeting (Noumea, New Caledonia, 23-27 July 2001). 33 pp.
- Chilvers, B.L. and Corkeron, P.J. 2001. Trawling and bottlenose dolphins' social structure. Proceedings of the Royal Society of London Series B Biological Sciences 268:1901-1905.
- Chilvers, B.L. and Corkeron, P. J. 2003. Abundance of Indo-Pacific bottlenose dolphins, *Tursiops aduncus*, off Point Lookout, Queensland, Australia. Marine Mammal Science 19:85-95.
- Cockcroft, V., DeKock, A., Lord, D. and Ross, G.. 1989. Organochlorines in bottlenose dolphins *Tursiops truncatus* from the east coast of South Africa. South African Journal of Marine Science 8:207-217.
- Connor, R.C., Smolker, R. and Bejder, L. 2006. Synchrony, social behaviour and alliance affiliation in Indian Ocean bottlenose dolphins, *Tursiops aduncus*. Animal Behaviour 72(6):1371-1378.
- Connor, R.C., Wells, R.S., Mann, J. and Read, A.J. 2000. The bottlenose dolphin, *Tursiops* spp: social relationships in a fission-fusion society. Pp. 91-126 in J. Mann, R.C. Connor, P.L. Tyack and H. Whitehead, eds. Cetacean Societies: Field Studies of Dolphins and Whales. University of Chicago Press. 433 pp.
- Corkeron, P.J. and Martin, A.R. 2004. Ranging and diving behaviour of two 'offshore' bottlenose dolphins, *Tursiops* sp., off eastern Australia. Journal of the Marine Biological Association of the United Kingdom 84:465-468.
- Dawbin, W.H. 1966. Porpoise and porpoise hunting in Malaita. Australian Natural History 15(7):207-211.
- Dawbin, W.H. 1972. Dolphins and whales. pp. 270-276 in P. Ryan, ed. Encyclopaedia of Papua and New Guinea. Melbourne University Press, Melbourne.
- Dizon, A.E. and Perrin, W.F., eds. 1997. Report of the workshop. pp. 3-48 in Molecular genetics of marine mammals. Society for Marine Mammalogy, Special Publication No. 3. Society for Marine Mammalogy, Lawrence, Kansas, USA.
- Duffield, D.A. and Wells, R.S. 1991. The combined application of chromosome, protein and molecular data for the investigation of social unit structure and dynamics in *Tursiops truncatus*. Report of the International Whaling Commission, Special Issue 13:155-169.
- Furry, C. and Harrison, P.L. 2008. Abundance, site fidelity and range patterns of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in two Australian subtropical estuaries. Marine and Freshwater Research 59:1015-1027.
- Gales, N.J. 1995. Hooker's sea lion (*Phocarctos hookeri*) recovery plan. New Zealand Department of Conservation, Threatened Species Recovery Plan Series No. 17.
- Harcourt, R.G. 2001. Advances in New Zealand mammalogy 1990-2000: pinnipeds. Journal of the Royal Society of New Zealand 31:135-160.
- Harwood, M.B. and Hembree, D. 1987. Incidental catch of small cetaceans in the offshore gillnet fishery in northern Australian waters: 1981-1985. Report of the International Whaling Commission 37:363-367.

Houde, M., Pacepavicius, G., Wells, R.S., Fair, P.A., Letcher, R.J., Alae, M., Bossart, G.D., Hohn, A.A., Sweeney, J.C., Solomon, K.R. and Muir, D.C.G. 2006. Polychlorinated biphenyls (PCBs) and hydroxylated polychlorinated biphenyls (OH-PCBs) in bottlenose dolphins (*Tursiops truncatus*) from the western Atlantic and the Gulf of Mexico. *Environmental Science & Technology* 40:5860-5866.

IWC 1996a. Report of the Scientific Committee. Report of the International Whaling Commission 46:49-106.

IWC 1996b. Chairman's Report of the Forty-Seventh Annual Meeting. Report of the International Whaling Commission 46:13-48.

IWC 1997. Report of the Scientific Committee. Report of the International Whaling Commission 47:57-121.

IWC 2002. Report of the Scientific Committee. *Journal of Cetacean Research and Management* 4 (suppl.):1-92.

IWC 2005. Report of the Scientific Committee. *Journal of Cetacean Research and Management* 7 (suppl.):1-76.

IWC 2006. Report of the Scientific Committee. *Journal of Cetacean Research and Management* 8 (suppl.):1-77.

Kahn, B. 2003. Derawan Archipelago Rapid Ecological Assessment - Visual and Acoustic Cetacean Survey and Training Program. Technical Report - AE0301. The Nature Conservancy - East Kalimantan Marine Program. 34 pp.

Kahn, B. 2004. Solomon Islands rapid ecological assessment oceanic cetaceans and associated habitats: May-June 2004. Technical report prepared for the Solomon Islands Marine Assessment Coordinating Committee by Apex Environmental, Cairns, Australia.

Kahn, B. 2005. Indonesia Oceanic Cetacean Program Activity Report - January – February 2005: The rapid ecological assessment (REA) of oceanic cetaceans and associated habitats in the Bali-Lombok Strait region; Capacity building workshop: 'Indonesia's Whales and Dolphins - A Tourism Perspective'; Indonesian Marine Protected Areas (MPA) and cetaceans – the Solor Alor MPA development. 21 pp.

Kahn, B. 2006. Oceanic Cetaceans and Associated Habitats in the Western Solomon Islands. In: A. Green, P. Lokani, W. Atu, P. Ramohia, P. Thomas and J. Almany, eds. *Solomon Islands Marine Assessment: Technical Report of Marine Survey - May 13 to June 17, 2004*. The Nature Conservancy - Pacific Island Countries Report No. 1/06. pp 445-515.
(<http://conserveonline.org/workspaces/pacific.island.countries.publications/SIMARReport>).

Kahn, B. 2007a. A rapid ecological assessment of oceanic cetaceans, associated habitats (near-shore yet deep-sea) and traditional dolphin drives in the Solomon Islands. Abstracts of the 17th Biennial Conference on the Biology of Marine Mammals, 29 November to 3 December 2007, Cape Town, South Africa.

Kahn, B. 2007b. *Marine Mammals of the Raja Ampat Islands: Visual and Acoustic Cetacean Survey & Training Program*. Technical Report to Conservation International - Indonesia Program. 57 pp.

- Kannan, K., Blankenship, A.L., Jones, P.D. and Giesy, J.P. 2000. Toxicity reference values for the toxic effects of polychlorinated biphenyls to aquatic mammals. *Human Ecology and Risk Assessment* 6:181–201.
- Kemper, C. M. 2004. Osteological variation and taxonomic affinities of bottlenose dolphins, *Tursiops* spp., from South Australia. *Australian Journal of Zoology* 52:29-48.
- Klatsky, L.J., Wells, R.S. and Sweeney, J.C. 2007. Offshore bottlenose dolphins (*Tursiops truncatus*): movement and dive behavior near the Bermuda Pedestal. *Journal of Mammalogy* 88:59-66.
- Kogi, K., Hishii, T., Imamura, A., Iwatani, T. and Dudzinski, K.M. 2004. Demographic parameters of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) around Mikura Island, Japan. *Marine Mammal Science* 20:510-526.
- Krützen, M, and Sherwin, W.B. 2004. Does genetic differentiation imply speciation? Phylogenetic and paternity analyses show that this is not the case in West-Australian bottlenose dolphins (*Tursiops* sp.). Paper prepared for Symposium on Cetacean Systematics: Approaches in genetics, morphology and behavior, 28-29 April 2004, La Jolla, California.
- Krützen, M., Sherwin, W.B., Berggren P. and Gales, N. 2004. Population structure of an inshore cetacean revealed by microsatellite and mtDNA analysis: bottlenose dolphins (*Tursiops* sp.) in Shark Bay, Western Australia. *Marine Mammal Science* 20:28-47.
- Kurihara, N. and Oda, S. 2007. Cranial variation in bottlenose dolphins *Tursiops* spp. from the Indian and western Pacific Oceans: additional evidence for two species. *Acta Theriologica* 52(4):403-418.
- Lacy, R.C. 2000a. Structure of the VORTEX simulation model for population viability analysis. *Ecological Bulletins* 48:191-203.
- Lacy, R.C. 2000b. Considering threats to the viability of small populations. *Ecological Bulletins* 48:39-51.
- Lacy, R.C., Borbat, M. and Pollak, J.P. 2008. VORTEX: A Stochastic Simulation of the Extinction Process. Version 9.91. Chicago Zoological Society, Brookfield, Illinois, USA.
- Lawson, T. 2001. Observer data held by the oceanic fisheries programme covering tuna fishery bycatches in the western and central Pacific Ocean. 14th Meeting of the Standing Committee on the Tuna and Billfish, SCTB 14, Noumea, New Caledonia, 9-16 August 2001. 42 pp.
- Leatherwood, S. and Reeves, R.R. 1982, Bottlenose dolphin (*Tursiops truncatus*) and other toothed cetaceans. Pp. 369-414 in J.A. Chapman and G.A. Feldhamer, eds. *Wild Mammals of North America: Biology, Management, and Economics*. Johns Hopkins University Press, Baltimore.
- Lukoschek, V. and Chilvers, B.L. 2008. A robust baseline for bottlenose dolphin abundance in coastal Moreton Bay: a large carnivore living in a region of escalating anthropogenic impacts. *Wildlife Research* 35:593-605.
- Mann, J., Connor, R.C., Barre, L.M. and Heithaus, M.R. 2000. Female reproductive success in bottlenose dolphins (*Tursiops* sp.): life history, habitat, provisioning, and group size effects. *Behavioral Ecology* 11:210-219.

- Miller, C. 2007. Current State of Knowledge of Cetacean Threats, Diversity and Habitats in the Pacific Islands Region. Whale and Dolphin Conservation Society Australasia Inc. 98 pp.
- Milner-Gulland, E.J. and Akçakaya, H.R. 2001. Sustainability indices for exploited populations. *Trends in Ecology & Evolution* 16:686-692.
- MMC. 2007. Report of the workshop on assessing the viability of endangered marine mammals in U.S. waters, 13-15 September 2005, Savannah, Georgia. Marine Mammal Commission, Bethesda, Maryland, USA.
- Möller, L.M. and Beheregaray, L.B. 2004. Genetic evidence for sex-biased dispersal in resident bottlenose dolphins (*Tursiops aduncus*). *Molecular Ecology* 13:1607-1612
- Möller, L.M., Beheregaray, L.B., Harcourt, R.G. and Krützen, M. 2001. Alliance membership and kinship in wild male bottlenose dolphins (*Tursiops aduncus*) of southeastern Australia. *Proceedings of the Royal Society of London Series B Biological Sciences* 268:1941-1947.
- Möller, L.M., Beheregaray, L.B., Allen, S.J. and Harcourt, R.G. 2006. Association patterns and kinship in female Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) of southeastern Australia. *Behavioral Ecology and Sociobiology* 61:109-117.
- Möller, L.M., Bilgmann, K., Charlton-Robb, K. and Beheregaray, L.B. 2008. Multi-gene evidence for a new bottlenose dolphin species in southern Australia. *Molecular Phylogenetics and Evolution* 49:674-681.
- Möller L.M., Wiszniewski J., Allen S.J. and Beheregaray, L. 2007. Habitat type promotes rapid and extremely localized genetic differentiation in dolphins. *Marine and Freshwater Research* 57:640-648.
- Morisaka, T., Shinohara, M., Nakahara, F. and Akamatsu, T. 2005. Geographic variations in the whistles among three Indo-Pacific bottlenose dolphin *Tursiops aduncus* populations in Japan. *Fisheries Science* 71:568-576.
- Natoli, A., Peddemors, V.M. and Hoelzel, A.R. 2004. Population structure and speciation in the genus *Tursiops* based on microsatellite and mitochondrial DNA analyses. *Journal of Evolutionary Biology* 17:363-375.
- New Zealand Ministry of Fisheries. 2007. Draft Threat Management Plan (TMP) for Hector's dolphins (<http://www.fish.govt.nz/en-nz/Consultations/Under+Review/hector/default.htm>).
- Okamura, H., Iwasaki, T. and Miyashita, T. 2008. Toward sustainable management of small cetacean fisheries around Japan. *Fisheries Science* 74:718-729.
- Omata, O., Hammond, T., Itoh, K. and Murata, K. 2005. Antibodies against *Toxoplasma gondii* in the Pacific bottlenose dolphin (*Tursiops aduncus*) from the Solomon Islands. *Journal of Parasitology* 91(4):965-967.
- Oremus, M., Poole, M.M., Steel, D. and Baker, C.S. 2007. Isolation and interchange among insular spinner dolphin communities in the South Pacific revealed by individual identification and genetic diversity. *Marine Ecology Progress Series* 336:275-289.
- O'Shea, T.J. 1999. Environmental contaminants and marine mammals. Pp. 485-564 in J.E. Reynolds, III and S.A. Rommel, eds. *Biology of Marine Mammals*. Smithsonian Institution Press, Washington, D.C.

- Parsons, K.M., Durban, J.W., Claridge, D.E., Herzing, D.L., Balcomb, K.C. and Noble, L.R. 2006. Population genetic structure of coastal bottlenose dolphins (*Tursiops truncatus*) in the northern Bahamas. *Marine Mammal Science* 22:276-298.
- Perrin, W.F., Robertson, K.M., Van Bree, P.J.H. and Mead, J.G. 2007. Cranial description and genetic identity of the holotype specimen of *Tursiops aduncus* (Ehrenberg, 1832). *Marine Mammal Science* 23:343-357.
- Preen, A. 2004. Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. *Biological Conservation* 118(2):205-218.
- Quéroil, S., Silva, A.M., Freitas, L., Prieto, R., Magalhães, S., Dinis, A., Alves, F., Matos, J., Mendonca, D., Hammond, P.S. and Santos, R.S. 2007. High gene flow in oceanic bottlenose dolphins (*Tursiops truncatus*) of the North Atlantic. *Conservation Genetics* 8:1405-1419.
- Read, A.J., Urian, K.W., Wilson, B. and Waples, D.M. 2003 Abundance of bottlenose dolphins in the bays, sounds, and estuaries of North Carolina. *Marine Mammal Science* 19:59-73.
- Reeves, R.R., Leatherwood, S., Stone, G.S. and Eldredge, L.G. 1999. Marine mammals in the area served by the South Pacific Regional Environment Programme (SPREP). South Pacific Regional Environment Programme, Apia, Western Samoa. 48 pp.
- Reeves, R.R., Perrin, W.F., Taylor, B.L., Baker, C.S. and Mesnick, S.L., eds. 2004. Report of the Workshop on Shortcomings of Cetacean Taxonomy in Relation to Needs of Conservation and Management; April 30 - May 2, 2004, La Jolla, California. NOAA Technical Memorandum NMFS-SWFSC-363. 94 pp.
- Reeves, R.R., B.D. Smith, E.A. Crespo and G. Notarbartolo di Sciara (compilers). 2003. Dolphins, Whales and Porpoises: 2002-2010 Conservation Action Plan for the World's Cetaceans. IUCN/SSC Cetacean Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 139 pp.
- Reilly, S.B. and Barlow, J. 1986. Rates of increase in dolphin population size. *Fishery Bulletin, U.S.* 84:527-533.
- Ross, G., Gales, N., Brownell, R., Reeves, R. and Gulland, F. 2003a. Live-capture and trade of bottlenose dolphins, Solomon Islands. *Species (Newsletter of the Species Survival Commission IUCN-The World Conservation Union)* 40:[4-5].
- Ross, G., Gulland, F., Gales, N., Brownell, R. and Reeves, R. 2003b. Report of a Fact-finding Visit to the Solomon Islands, 9-12 September 2003. Unpublished.
- Schwacke, L.H., Voit, E.O., Hansen, L.J., Wells, R.S., Mitchum, G.B., Hohn, A.A. and Fair, P.A. 2002. Probabilistic risk assessment of reproductive effects of polychlorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. *Environmental Toxicology and Chemistry* 21(12):2752-2764.
- Scott, M.D., Wells, R.S. and Irvine, A.B. 1990. A long-term study of bottlenose dolphins on the west coast of Florida. Pp. 235-244 *In*: S. Leatherwood and R.R. Reeves, eds., *The Bottlenose Dolphin*. Academic Press, San Diego. 653 pp.

- Sellas, A.B., Wells, R.S. and Rosel, P.E. 2005. Mitochondrial and nuclear DNA analyses reveal fine scale geographic structure in bottlenose dolphins (*Tursiops truncatus*) in the Gulf of Mexico. *Conservation Genetics* 6:715-728.
- Shimura, E. 1990. Honiara no iruka [Dolphins of Honiara]. *Isana* [Tokyo] 13:11-15.
- Shirakihara, M., Shirakihara, K., Tomonaga, J. and Takatsuki, M. 2002. A resident population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Amakusa, western Kyushu, Japan. *Marine Mammal Science* 18:30-41.
- Silva, A.M., Prieto, R., Magalhães, S., Seabra, M.I., Santos, R.S. and Hammond, P.S. 2008. Ranging patterns of bottlenose dolphins living in oceanic waters: implications for population structure. *Marine Biology* 156:179-192.
- Slooten, E. and Dawson, S.M. 2008. Sustainable levels of human impact for Hector's dolphins. *The Open Conservation Biology Journal* 2:37-43. (<http://www.bentham.org/open/toconsbj/openaccess2.htm>).
- Slooten E. and Lad, F. 1991. Population biology and conservation of Hector's dolphin. *Canadian Journal of Zoology* 69:1701-1707.
- Slooten, E. and Wade, P.R. 2007. Calculating limits for human impacts on small populations of marine mammals. Abstracts of the 17th Biennial Conference on the Biology of Marine Mammals, 29 November to 3 December 2007, Cape Town, South Africa.
- Smith, B.D., Jefferson, T.A., Leatherwood, S., Ho, D.T., Thuoc, C.V. and Quang, L.H. 1997. Investigations of marine mammals in Vietnam. *Asian Marine Biology* 14:145-172.
- SPREP. 2007. Pacific Islands Regional Marine Species Programme 2008-2012 - Apia, Samoa: SPREP, 2007. Secretariat of the Pacific Regional Environment Programme, Apia, Samoa.
- Steiner, A. and Bossley, M. 2008. Some reproductive parameters of an estuarine population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). *Aquatic Mammals* 34:84-92.
- Stensland, E., Carlén, I., Särnblad, A., Bignert, A. and Berggren, P. 2006. Population size, distribution, and behavior of Indo-Pacific bottlenose (*Tursiops aduncus*) and humpback (*Sousa chinensis*) dolphins off the south coast of Zanzibar. *Marine Mammal Science* 22:667-682.
- Takekawa, D. 1996a. Ecological knowledge of Fanalei villagers about dolphins: dolphin hunting in the Solomon Islands 1. *Senri Ethnological Studies* 42:55-65.
- Takekawa, D. 1996b. The method of dolphin hunting and the distribution of teeth and meat: dolphin hunting in the Solomon Islands 2. *Senri Ethnological Studies* 42:67-80.
- Taylor, B.L. 2005. Identifying units to conserve. pp. 149-162 in J.E. Reynolds III, W.F. Perrin, R.R. Reeves, S. Montgomery and T.J. Ragen, eds. *Marine Mammal Research: Conservation beyond Crisis*. Johns Hopkins University Press, Baltimore, USA.
- Taylor, B.L. and DeMaster, D.P. 1993. Implications of non-linear density dependence. *Marine Mammal Science* 9:360-371.

- Taylor, B.L., Wade, P.R., DeMaster, D.P. and Barlow, J. 2000. Incorporating uncertainty into management models for marine mammals. *Conservation Biology* 14:1243-1252.
- Tezanos-Pinto, G., Baker, C.S., Russell, K., Martien, K., Baird, R.W., Hutt, A., Stone, G., Mignucci-Giannoni, A.A., Caballero, S., Endo, T., Lavery, S., Oremus, M., Olavarría, C. and Garrigue, C. 2009. A worldwide perspective on the population structure and genetic diversity of bottlenose dolphins (*Tursiops truncatus*) in New Zealand. *Journal of Heredity* 100:11-24.
- Tezanos-Pinto, G., Garrigue, C., Oremus, M. and Baker, C.S. In preparation. Genetic identity of bottlenose dolphin biopsy samples collected in New Caledonia with a comparison to mtDNA control region sequences of *Tursiops aduncus* and *T. truncatus*.
- Viaud-Martinez, K.A., Brownell, R.L. Jr., Kommenou, A. and Bohonaka, A.J. 2008. Genetic isolation and morphological divergence of Black Sea bottlenose dolphins. *Biological Conservation* 141:1600-1611.
- Wade, P.R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. *Marine Mammal Science* 14(1):1-37.
- Wade, P.R., and Angliss, R.P. 1997. Guidelines for assessing marine mammal stocks: report of the GAMMS Workshop, April 3-5, 1996, Seattle, Washington. U.S. Dep. Commerce, NOAA Technical Memorandum NMFS-OPR-12, 93 pp. (http://www.nmfs.noaa.gov/pr/pdfs/sars/gamms_report.pdf).
- Wang, J.Y., Chou, L.S. and White, B.N. 1999. Mitochondrial DNA analysis of sympatric morphotypes of bottlenose dolphins (genus: *Tursiops*) in Chinese waters. *Molecular Ecology* 8:1603-1612.
- Wang, J.Y. and Yang, S-C. 2009. Indo-Pacific bottlenose dolphin, *Tursiops aduncus*. In: W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. *Encyclopedia of Marine Mammals*. Second Edition. Elsevier, Inc., San Diego, California.
- Wang, J.Y. and Yang, S-C. 2005. Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) of Nan Wan and adjacent waters in southern Taiwan. P. 156 in W.F. Perrin, R.R. Reeves, M.L.L. Dolar, T.A. Jefferson, H. Marsh, J.Y. Wang and J. Estacion, eds. *Report of the second workshop on the biology and conservation of small cetaceans and dugongs in South-east Asia*. CMS Technical Series Publication No. 9. UNEP/CMS Secretariat, Bonn, Germany.
- Waring G.T., Josephson, E., Fairfield-Walsh, C.P. and Maze-Foley, K. 2007. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2007. NOAA Technical Memorandum NMFS-NEFSC-205. 415 pp. (<http://www.nefsc.noaa.gov/nefsc/publications/tm/tm205/>).
- Wells, R.S. 1991. The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pp. 199-225 In: K. Pryor and K.S. Norris, eds. *Dolphin Societies: Discoveries and Puzzles*. University of California Press, Berkeley. 397 pp.
- Wells, R.S. 2000. Reproduction in wild bottlenose dolphins: Overview of patterns observed during a long-term study. Pp. 57-74 In: D. Duffield and T. Robeck, eds. *Bottlenose Dolphin Reproduction Workshop Report*. AZA Marine Mammal Taxon Advisory Group, Silver Spring, Maryland.
- Wells, R.S. 2003. Dolphin social complexity: lessons from long-term study and life history. Pp. 32-56 In: F.B.M. de Waal and P.L. Tyack, eds. *Animal Social Complexity: Intelligence, Culture, and Individualized Societies*. Harvard University Press, Cambridge, Massachusetts.

- Wells, R.S., Early, G.A., Gannon, J.G., Lingenfelter, R.G. and Sweeney, P. 2008. Tagging and tracking of rough-toothed dolphins (*Steno bredanensis*) from the March 2005 mass stranding in the Florida Keys. NOAA Technical Memorandum NMFS-SEFSC-574, 44 pp.
- Wells, R.S., Manire, C.A., Smith, D., Gannon, J.G., Fauquier, D. and Mullin, K.D. In press. Movements and dive patterns of a rehabilitated Risso's dolphin, *Grampus griseus*, in the Gulf of Mexico and Atlantic Ocean. Marine Mammal Science.
- Wells, R. S., Rhinehart, H. L., Cunningham, P., Whaley, J., Baran, M., Koberna, C. and Costa, D. P. 1999. Long-distance offshore movements of bottlenose dolphins. Marine Mammal Science 15:1098-1114.
- Wells, R.S. and Scott, M.D. 1990. Estimating bottlenose dolphin population parameters from individual identification and capture-release techniques. Report of the International Whaling Commission, Special Issue 12:407-415.
- Wells, R.S. and Scott, M.D. 1999. Bottlenose dolphin *Tursiops truncatus* (Montagu, 1821). Pp. 137-182 In: S.H. Ridgway and R. Harrison, eds. Handbook of Marine Mammals, Vol. 6: The Second Book of Dolphins and the Porpoises. Academic Press, San Diego, California. 486 pp.
- Wells, R.S. and Scott, M.D. 2002. Bottlenose dolphins (*Tursiops truncatus* and *T. aduncus*). Pp. 122-128 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of Marine Mammals. Academic Press, San Diego, California.
- Wells, R.S., Scott, M.D. and Irvine, A.B. 1987. The social structure of free-ranging bottlenose dolphins. Pp. 247-305 in Genoways, H., ed. Current Mammalogy, Vol. 1. Plenum Press, New York.
- Wells, R.S., Tornero, V., Borrell, A., Aguilar, A., Rowles, T.K., Rhinehart, H.L., Hofmann, S., Jarman, W.M., Hohn, A.A. and Sweeney, J.C. 2005. Integrating life history and reproductive success data to examine potential relationships with organochlorine compounds for bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. Science of the Total Environment 349:106-119.

Annex 1

LIST OF PARTICIPANTS

Robin W. Baird
Cascadia Research Collective
218 ½ W, 4th Ave, Olympia, WA 98506, USA
rwbaird@cascadiaresearch.org

Lui Bell
Secretariat of the Pacific Regional Environment Programme
PO Box 240, Apia, Samoa
LuiB@sprep.org

Robert L. Brownell, Jr.
NOAA Fisheries
1352 Lighthouse Ave, Pacific Grove, CA, USA
Robert.Brownell@NOAA.gov

Simon Childerhouse
South Pacific Whale Research Consortium & BPM NZ Ltd
PO Box 6110, Dunedin, New Zealand.
simon@blueplanetmarine.com

R.H. Defran
3610 Old Cobble Rd, San Diego, CA 92111, USA.
rh.defran@gmail.com

Claire Garrigue
Opération Cétacés
BP 12827, 98802 Noumea, New Caledonia
op.cetaces@lagoon.nc

Joe Horokou
Ministry of Environment, Conservation and Meteorology
Solomon Islands
horokoujoe@gmail.com

John Leqata
Ministry of Fisheries and Marine Resources
PO Box G13, Honiara, Solomon Islands
jleqata@fisheries.gov.sb

Cara Miller
Whale and Dolphin Conservation Society International/Flinders University
PO Box 228, Suva, Fiji
cara.miller@wdcs.org

Marc Oremus
Opération Cétacés & University of Auckland
BP 12827, 98802 Noumea, New Caledonia
m.oremus@auckland.ac.nz

Randall R. Reeves
Okapi Wildlife Associates
27 Chandler, Hudson, Quebec J0P 1H0, Canada
rrreeves@okapis.ca

Sue Miller Taii
Conservation International
PO Box 2035, Apia, Samoa
staei@conservation.org

Gabriela Tezanos-Pinto
University of Auckland
Private Bag 92019, Auckland, New Zealand
gaby@pachamama.co.nz

Paul Wade
National Marine Mammal Laboratory
NOAA, Alaska Fisheries Science Center, Seattle, WA 98115, USA
paul.wade@noaa.gov

John Y. Wang
Formosa-Cetus Research Group (Canada) & National Museum of Marine Biology & Aquarium (Taiwan)
310-7250 Yonge St, Thornhill, Ontario L4J 7X1, Canada
pccrassidens@rogers.com

Juney Ward
Ministry of Natural Resources and Environment
PO Private Bag, Apia, Samoa
Juney.Ward@mnre.gov.ws

Randall S. Wells
Chicago Zoological Society
c/o Mote Marine Lab, 1600 Ken Thompson Parkway, Sarasota, FL 34236, USA
rwells@mote.org

Ben Wilson
Scottish Association for Marine Sciences
Oban, Argyll, PA371QA, UK
ben.wilson@sams.ac.uk

WORKSHOP AGENDA

1. Introduction

- 1.1 Welcome and logistics (Bell, Reeves, Brownell)
- 1.2 Purpose and scope of workshop (Reeves, Brownell)
- 1.3 Report preparation, review and distribution (Reeves)
- 1.4 Appointment of rapporteurs
- 1.5 Discussion of agenda and procedures
- 1.6 Adoption of agenda
- 1.7 Available workshop documents

2. Assessment options

- 2.1 Management goals, management scales etc. (Wade)
- 2.2 Methods used for evaluating takes of small cetaceans (PBR, IWC, ASCOBANS, etc.) (Wade)
- 2.3 Case examples of management of takes of small cetaceans (Wade)
- 2.4 Sustainability and CITES (Brownell, Reeves)

3. Review of *Tursiops* biology

- 3.1 Distribution around Solomon Islands (*Tursiops* spp.) including photo-id (Defran, Kahn)
- 3.2 Distribution and habitat (Baird, Wang)
- 3.3 Relevant life history (e.g. r_{max}), behaviour (e.g. social factors relevant to sustainability of removals) and ecology (Wells, Wang, Baird)
- 3.4 Site fidelity and tenacity (short- and long-term) (Baird, Wells, Wilson)
- 3.5 Inter-island movements (Baird)

4. Dolphin hunting in the Solomon Islands

- 4.1 Drive fisheries (Kahn)
- 4.2 Harpoon fisheries (Kahn)
- 4.3 Live-capture (Wells for global overview of *Tursiops*, Brownell for Solomon Is.)

5. Threat factors other than direct removals

- 5.1 Incidental mortality in fisheries (bycatch) (Perrin, Brownell)
- 5.2 Habitat modification, degradation or destruction (e.g. reefs, harbours) (Kahn, Wang)
- 5.3 Noise (e.g. from boat traffic, oil & gas development activities)
- 5.4 Toxic effects from chemical pollution of dolphins and/or their prey (Wells)

6. Genetics

- 6.1 Insular populations (Tezanos-Pinto, Oremus, Wang)
- 6.2 Regional populations (Tezanos-Pinto, Oremus)
- 6.3 Species and subspecies (Perrin)
- 6.4 Definition of units to conserve (Perrin)

7. Methods to estimate population size for small cetaceans

7.1 Aerial survey (Wade)

7.2 Vessel survey (Wade)

7.3 Photo-ID mark-recapture (Wade, Baird, Wells)

7.4 Comparative data from other *T. aduncus* populations (Brownell)

7.5 Experience to date in Solomon Is. with photo-id (Defran)

8. Synthesis

8.1 Ideal vs acceptable

8.2 National vs regional assessments

8.3 Selecting the best research programme to support assessment

BIOGRAPHIES OF WORKSHOP PARTICIPANTS

Robin W. Baird is a research biologist with Cascadia Research Collective, based in Olympia, Washington, USA, as well as an adjunct professor at Portland State University and an affiliate assistant professor at the University of Washington. He has been studying cetaceans since 1985, with research primarily focusing on small cetacean behaviour, ecology, population structure and population size. Since 1999 he has undertaken a study of population structure and size of island-associated cetaceans, including bottlenose dolphins, around the main Hawaiian Islands. He has authored or co-authored more than 60 peer-reviewed publications, has served as a reviewer for more than 40 different scientific journals, is currently an associate editor of the journal *Marine Mammal Science*, and is a member of the Marine Mammal Advisory Committee of the Western Pacific Fisheries Management Council.

Lui Bell is SPREP's Marine Species Officer, responsible for its regional marine species programme, which currently focuses on dugongs, marine turtles and cetaceans. SPREP has a regional Action Plan for each of these three groups of marine animals, highlighting priority actions and intended to guide conservation work for these species in the Pacific Islands region.

Robert L. Brownell, Jr. is Senior Scientist for International Protected Resources, National Oceanic and Atmospheric Administration, Southwest Fisheries Science Center, Pacific Grove, California, USA. He has conducted research on the biology and conservation of whales, dolphins and porpoises throughout the world, leading major studies in Mexico, South America, Japan and Russia. He has published more than 200 scientific papers, book chapters and management documents on various aspects of cetacean biology, conservation and management. He has been a member of the U.S. delegation to the International Whaling Commission (IWC) since 1975 and served as vice-chair and chair of the IWC Scientific Committee from 1985 to 1991. He also served as Chief of Marine Mammal Research for the U.S. Fish and Wildlife Service from the late 1970s to 1991, president of the Society for Marine Mammalogy from 1987 to 1989, Science Advisor to the Assistant Secretary for Oceans at the U.S. Department of State between 1991 and 1993, and director of the Marine Mammal Division at the Southwest Fisheries Science Center in La Jolla, California, from 1993 to 2002. He has been a member of IUCN marine mammal specialist groups for about 30 years and served three terms on the Committee of Scientific Advisers of the U.S. Marine Mammal Commission.

Simon Childerhouse is director of Blue Planet Marine, an environmental consultancy, and coordinator of the South Pacific Whale Research Consortium. He previously worked for more than ten years as a marine mammal scientist for the New Zealand Department of Conservation, with a focus on marine mammal conservation and protection. He has been a member of the IWC Scientific Committee since 1998, including eight years as head of the New Zealand delegation. He chaired IWC Sub-committees on Southern Hemisphere humpback whales and Southern Hemisphere whale stocks. At present, Childerhouse is based in Dunedin, NZ, but he has worked on marine mammals in many parts of the world including New Zealand, Australia, the South Pacific Islands, South America and the United States.

R.H. Defran is director of the Cetacean Behavior Laboratory at San Diego State University in California. He obtained his Ph.D. in experimental psychology from Bowling Green State University in Bowling Green, Ohio, in 1970 and since then has been a professor in the Psychology Department at San Diego State University. In late 1983, Defran began work with the National Marine Fisheries Service, NOAA Southwest Fisheries Science Center, La Jolla, California, where he assumed responsibility for an ongoing boat-based photo-identification project designed to assess the population size and range characteristics of bottlenose dolphins in northern San Diego County. Since 1984, Defran has carried out and directed the Cetacean Behavior Laboratory's population studies of bottlenose dolphins along the southern California

and Baja California Norte (Mexico) coastline, in Belize (Central America), in Florida's Indian River Lagoon, in the estuarine and coastal waters near Charleston, South Carolina (USA), and most recently in the coastal waters of Guadalcanal in the Solomon Islands.

Claire Garrigue is a senior scientist for Opération Cétacés, a nongovernmental organization conducting research on marine mammals. She is a founding member of the South Pacific Whale Research Consortium. She has conducted research on the ecology and conservation of humpback whales and dugongs in New Caledonia, south-western Pacific. She has published over 20 scientific papers and management documents on various aspects of humpback whale biology, conservation and management. She was a member of the French delegation to the International Whaling Commission in 2000 and 2008 and is a member of IUCN/SSC Cetacean Specialist Group.

Joe Horokou has been with the Environment and Conservation Division in the Solomon Islands Ministry of Environment, Conservation and Meteorology for the past 15 years. His professional background and technical expertise are in environmental management and planning. In 2006 he participated in a 2-week training course on dolphin survey methods in Papua New Guinea, which included open-ocean and coastal surveys and instruction in techniques for identifying various cetacean species at sea.

John Leqata is currently the Chief Fisheries Officer (Research) (Acting) for the Inshore Fisheries Management Division in the Ministry of Fisheries and Marine Resources, based in Honiara, Solomon Islands. In 1988, after graduating from the University of the South Pacific in Fiji, he joined the Research Section of the Department of Fisheries. He has been involved in a number of scientific research programmes and projects, especially the Baitfish Project from 1988-1990, the Regional Tuna Tagging Project from 1990-1991 and the Turtle Tagging Project from 1992-1993. He was a local counterpart in the Underwater Visual Census project (UVC) from 1993-1995 and in the OFCF/SIG Atoll Project from 1996-2000. He was involved with a French government research institute in the collection of samples of deepwater benthic fauna and flora in 2001, 2004 and 2007, and in several in-country research activities, e.g. stock assessment surveys of vertebrates and invertebrates such as reef fishes, trochus, goldlips, sea cucumbers, clams and green snails. He has collaborated in fisheries-related activities with NGOs such as TNC, WWF and FSPI and with CROP agencies such as SPC, WorldFish Center, SPREP and FFA. He has been a co-author of several reports and scientific journal articles. He was recently appointed (2008) as Coordinator of the Dolphin Stock Assessment and Monitoring Project (for the drive hunt) in the Ministry of Fisheries and Marine Resources.

Cara Miller is a lecturer at Flinders University, South Australia, and leads the Pacific Islands Programme of the Whale and Dolphin Conservation Society International. She completed her post-graduate studies in the United States where she obtained a masters degree in applied statistics, specifically for estimating wildlife abundance using mark-recapture methods, and a Ph.D. for research on habitat and population assessment of a small, coastal population of bottlenose dolphins in the northern Gulf of Mexico. She has since been involved in research on populations of Indo-Pacific bottlenose dolphins along the South Australian coast and on cetacean diversity across the Pacific Islands region – with ongoing work in Papua New Guinea, Federated States of Micronesia and Fiji. In addition, she has been involved in numerous training workshops with participants from those countries as well as Kiribati, Marshall Islands, Niue, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. She authored a recent review entitled “Current State of Knowledge of Cetacean Threats, Diversity and Habitat in the Pacific Islands Region,” has helped develop regional cetacean action plans and agreements, and is currently a research fellow at the University of the South Pacific in Fiji.

Marc Oremus is an honorary research fellow at the University of Auckland, currently based in New Caledonia where he works with the nongovernmental organization Opération Cétacés. He recently completed his Ph.D. at the University of Auckland, investigating population structure and social systems

in several species of Delphinidae. He is primarily interested in the molecular ecology and demography of small cetaceans in the South Pacific. As a member of the South Pacific Whale Research Consortium, he has been conducting research on cetacean populations in various parts of the region, including French Polynesia, New Zealand, Australia, New Caledonia, Samoa and Tuvalu. His current project is to assess the genetic and demographic status of *Tursiops aduncus* and *Stenella longirostris* in New Caledonia.

Randall Reeves, a consultant based in Hudson, Quebec (near Montreal, Canada), is chairman of the IUCN/SSC Cetacean Specialist Group (CSG). He has a masters degree in public policy from Princeton University and a Ph.D. in geography from McGill University. During the 1980s and 1990s he was involved in field research on bowhead whales in Alaska, the Canadian Arctic and Greenland, and on North Atlantic right whales. He has conducted field research on river dolphins in Asia and South America and archival research on the history of whaling worldwide. As CSG chairman since 1996, Reeves has been responsible for preparing and evaluating Red List assessments, drafting action plans for threatened species and populations, and advising government agencies, intergovernmental bodies and nongovernmental organizations on science and conservation issues. He has published numerous articles in scientific journals and co-authored or co-edited several books including *The Bottlenose Dolphin* (Academic Press, 1990), *Conservation and Management of Marine Mammals* (Smithsonian Institution Press, 1999), *Guide to Marine Mammals of the World* (Alfred A. Knopf, 2002) and *Marine Mammal Research: Conservation Beyond Crisis* (Johns Hopkins University Press, 2005).

Gabriela Tezanos-Pinto is a Ph.D. candidate at the University of Auckland. Since 1994, she has been pursuing research on various aspects of the biology of coastal small cetaceans, such as the Commerson's dolphin, Hector's dolphin and Burmeister's porpoise. Her Ph.D. thesis focuses on the population structure, genetic diversity, demographic parameters and abundance of bottlenose dolphins inhabiting waters of the North Island, New Zealand. The results of her work on population structure, including a comprehensive worldwide comparison of 19 regional populations of bottlenose dolphins spanning three ocean basins, were recently published in the *Journal of Heredity*. This placed the regional differences found among New Zealand coastal populations in a worldwide context and provided new insights on the pattern of mitochondrial DNA diversity associated with habitat specialization and ecotype formation in *Tursiops truncatus*. She is currently collaborating with other researchers in the Pacific to review the genetic structure and taxonomy of *Tursiops* in this region.

Paul Wade is a research biologist in the Cetacean Program at the National Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA Fisheries, Seattle, Washington (<http://www.afsc.noaa.gov/nmml/cetacean/>), and an affiliate professor at the School of Fisheries and Aquatic Sciences, University of Washington. His research focuses on the ecology, population dynamics and conservation biology of cetaceans, and the use of modelling and quantitative methods in conservation and management. He received a Ph.D. from Scripps Institution of Oceanography having investigated the abundance and population dynamics of spotted and spinner dolphins in the eastern tropical Pacific. He has extensive experience (>20 surveys) in designing and conducting cetacean surveys from small boats, large ships and airplanes, on species including bottlenose dolphins, spotted and spinner dolphins, Hector's dolphins, harbour and Dall's porpoises, killer whales, humpback whales and right whales. He is a member of the U.S. delegation to the IWC Scientific Committee and of the Cetacean Specialist Group.

John Y. Wang is the principal biologist and co-founder of *FormosaCetus* Research and Conservation Group, an adjunct professor at Trent University, an affiliate professor at George Mason University and an adjunct researcher at the National Museum of Marine Biology and Aquarium of Taiwan. He has conducted research on cetaceans in Asia, North America and South America, with a primary focus on the biology and conservation of coastal small cetaceans in eastern and south-eastern Asia that are seriously threatened by human activities. These include the Indo-Pacific humpback dolphin, Indo-Pacific bottlenose dolphin and finless porpoise. For his Ph.D., he investigated the taxonomy of bottlenose dolphins in

Chinese waters using genetic, external morphological and osteological analyses, and he recently extended that approach to studies of finless porpoises in Chinese waters. Also, Wang has worked on abundance estimation of populations using both line-transect methods and mark-recapture analysis of photo-identification data and on the population genetics of small cetaceans. He is on the editorial board of the *Latin American Journal of Aquatic Mammals* and serves on the Honorary Advisory Committee of the Hong Kong Dolphin Conservation Society. He is a longstanding member of the Cetacean Specialist Group and a member of the International Cetacean Bycatch Taskforce.

Juney Ward is Senior Marine Conservation Officer in the Division of Environment and Conservation, Samoa Ministry of Natural Resources and Environment. She has been working on cetaceans since 2003, specifically documenting the whales and dolphins found in Samoan waters and carrying out awareness and education programmes to promote their protection.

Randall S. Wells is a senior conservation scientist with the Chicago Zoological Society, a senior scientist at Mote Marine Laboratory, and an adjunct professor of Ocean Sciences at the University of California, Santa Cruz (UCSC). He received his doctorate from UCSC and a postdoctoral fellowship from Woods Hole Oceanographic Institution. His research and conservation efforts involving cetaceans and manatees have led to more than 150 publications, including four books. His primary efforts are currently with the Sarasota Dolphin Research Program, studying the ecology, behaviour, life history, health and responses to human activities of the long-term resident population of bottlenose dolphins in Sarasota Bay, Florida. This programme, initiated in 1970 and currently involving a span of at least five generations of resident dolphins, uses photo-identification surveys, biopsy darting for genetic and contaminant sampling, capture-release for health assessment and life history studies, and focal animal behavioural observations, to provide unique research and training opportunities for colleagues and students from around the world. In addition to bottlenose dolphin research, Wells has studied the behaviour of Hawaiian spinner dolphins and of blue, gray and humpback whales, the ranging and dive patterns of franciscana dolphins off Argentina, the effects of offshore industrial activities on bowhead whales, the impacts of boat traffic on manatees, and the reintroduction of captive and rehabilitated dolphins back into their native waters. Wells is president-elect of the Society for Marine Mammalogy. He chairs the NOAA/USFWS Working Group on Marine Mammal Unusual Mortality Events and serves on the NOAA/USFWS Atlantic Scientific Review Group. He is a longstanding member of the Cetacean Specialist Group.

Ben Wilson is a lecturer at the Scottish Association for Marine Science. He has worked on the behavioural ecology, population biology and conservation of marine mammals since 1990. The majority of his research has focused on the use of photo-identification to study the ecology of bottlenose dolphins in coastal habitats. He has practical experience of small cetacean research and management at a variety of levels from the local (scientific committee of the Hebridean Whale and Dolphin Trust, UK) to the global (UK delegate to the IWC Scientific Committee). He has published more than 25 scientific papers and three books on small cetaceans.

TRADITIONAL DRIVE HUNTING OF DOLPHINS IN THE SOLOMON ISLANDS

Although not the primary focus of the workshop, it was recognised that the sustainability of traditional dolphin hunting in the Solomon Islands is of concern and should be investigated in more detail, especially given anecdotal evidence of local extirpation of the melon-headed whale.

The practice of hunting dolphins by driving them to shore was active at least as long ago as the 19th century. Despite periods of cessation at some sites, drive hunting has taken place on Malaita since the mid-20th century. The objectives are to obtain teeth (used as bride price, traditional currency and adornments) and meat, some of which is sold locally and in the capital, Honiara (Kahn 2006). In recent decades, drive hunts have been conducted only by particular villages on the island of Malaita, specifically: Fanalei, Walinde (Walande according to Kahn 2006), Sulufoa, Feresubua, Fourau, Mbita-ama (Bita 'Ama according to Kahn 2006).

Observations in Fanalei (a town of about 700 people on the south-eastern coast of Malaita) between 1990 and 1994 indicated that the most commonly taken species and primary target of the drive hunts was the pantropical spotted dolphin (*Stenella attenuata*) (Takekawa 1996a,b). The next most frequently taken species was the spinner dolphin (*Stenella longirostris*). Fraser's dolphins (*Lagenodelphis hosei*) were also taken at times. Among the other species that have been observed to be taken in the Solomon Islands drive hunts are the striped dolphin (*Stenella coeruleoalba*), common dolphin (*Delphinus* sp.), rough-toothed dolphin (*Steno bredanensis*), Risso's dolphin (*Grampus griseus*), bottlenose dolphin (*Tursiops* sp.) and, historically, the melon-headed whale (*Peponocephala electra*) (Dawbin 1966; Dawbin 1972; Takekawa 1996a,b). The melon-headed whale was a prized target historically because its teeth are reserved for wedding dowry for family members of community leaders as well as for special gifts to dignitaries. However, this species is no longer hunted, apparently because its numbers and availability have declined to too great an extent (Takekawa 1996a). Kahn (2004) specifically interviewed the village elders in charge of the traditional hunt and reported that *P. electra* have not been seen or caught by the hunters at Fanalei and Bita 'Ama for many decades.

An average of about 840 small cetaceans (approximate range from <50 in 1979 to ~2000 in 1986), mainly spotted and spinner dolphins, reportedly were taken per year at Fanalei from 1976 to 1993 (Takekawa 1996b). Approximate catches at Fanalei between 1999 and 2004, as reported in interviews in June 2004, were: 700 in 1999, 800 in 2000, (no data in 2001), 700 in 2002, 1200 in 2003 and 600 in 2004 (Kahn 2006). Kahn was told that 40-60 canoes participated in the drive hunting at Fanalei in 2004, compared with only 10-16 three human generations previously. He also reported that a catch of approximately 2000 dolphins at Fanalei in 1965 was the highest experienced by the current human generation (no mention was made of the ~2000 catch in 1986 reported by Takekawa 1996b). Kahn (2006) was told by elders at Bita 'Ama that although their drive hunting had stopped at an unspecified time in the past, they were planning to resume it in 2006 and by 2004 they had already begun preparations, such as the selection of specific trees for making hunting canoes. The workshop had no confirmation that this planned resumption had occurred. Kahn (2004) also reported that the people of Walande, a village near Fanalei, maintained some level of drive hunting effort in 2004 (30-40 canoes involved) but were not very successful (i.e. they made no catch that year).

No definite information was available to the workshop on whether Indo-Pacific bottlenose dolphins are or are not taken in the dolphin drives. Kahn (2006) reported from interview information that although the Fanalei people do target bottlenose dolphins, he was told, as was Takekawa, that *Tursiops* do not respond to the noise from clapping stones underwater in the same way as other dolphins. Instead of a fright reaction that allows them to be driven, bottlenose dolphins exhibit curiosity and approach the boats.

In workshop discussions, it was noted that reported catch levels at Fanalei (e.g. 600-800 dolphins per year) over the 4-month hunting season (January-April) seemed high for a village of only 700 people. However, the teeth (and meat?) may be traded or sold widely to other villages on Malaita as well as other islands, so it should not be assumed that the entire catch would need to be consumed locally.

It was also noted that two different types of spinner dolphins are caught at Fanalei. It is unlikely that removals of hundreds per year could be sustained if the spinner populations hunted off Honiara formed small resident groups as they do in some other oceanic island areas (e.g. Hawaii, French Polynesia). There is a need for rigorous identification of species (and subspecies) involved in the hunt.

Leqata advised the workshop of a 3-year programme initiated by the Solomon Islands Government (Ministry of Fisheries) earlier in 2008 to investigate social, economic and cultural aspects of drive hunting on Malaita. He stressed that the hunting was strictly seasonal and limited to the months of January through April. Also, local villagers hunt within the boundaries of fishing zones that have long been recognized from practice and tradition. Malaita is the only part of the Solomon Islands where dolphin drives are conducted at present (i.e. no similar hunts are thought to take place in the other eight provinces). Although the study will focus on villages where the tradition of dolphin driving has been maintained, there will be some survey work in other areas as well. Participants urged Leqata to incorporate into his study design the standard collection of morphometric data, photographs, skulls and genetic samples.

Horokou reported that his department (Ministry of Environment) is planning surveys of species, including Indo-Pacific bottlenose dolphins, that have been or could be subject to trade under CITES. Both he and Leqata welcomed expert advice in the development and design of their survey work.

Kahn (2006) expressed concern about the low diversity and low numbers of small cetaceans observed during his survey in 2003, noting that Solomon Islands waters ranked low compared to other regions with similar habitat types where comparable rapid ecological assessments had been carried out, in particular eastern Indonesia (i.e. Kahn 2003, 2005, 2007b)

USING GENETICS TO ASSESS THE SUSTAINABILITY OF THE TRADITIONAL DOLPHIN HUNT IN THE SOLOMON ISLANDS – MARC OREMUS

Introduction

Genetic tools may provide important information on the past, present and future of the traditional drive-hunt. Here, the potential sources of genetic material are reviewed along with some of the questions that could be addressed using genetic analyses. The conservation-related questions are classified as either *necessary* (i.e. requiring urgent investigation) or *desirable* (i.e. to be addressed if possible).

Potential sources of genetic material

- Tissue samples from dolphins taken in the traditional drive hunt (A)
- DNA from teeth collected in the past (“historical” samples). Note: The feasibility of using such samples needs to be assessed, as cultural and technical issues might preclude obtaining adequate DNA material from the teeth (B)
- Biopsy sampling during boat surveys in the Solomon Islands (C)
- Samples from other regions (Genbank, collaborations) (D)

Conservation-related questions

(For each question, the potential source or sources of genetic material is/are indicated in brackets by the appropriate letter or letters from the above list.)

- What species are currently exploited by the traditional drive-hunt? This question could be addressed using DNA sequences (DNA surveillance) although it is recognised that phylogenetic species identification in cetaceans can be complicated, especially for delphinids. Therefore, morphological data and photographs (preferably with carcasses oriented in a standard manner to facilitate species identification) should also be collected to address this question. (A) *Necessary*
- What are the current levels of genetic diversity within the exploited populations? (A+C) *Necessary*
- What are the geographic boundaries of the targeted populations of dolphins based on genetic information (local and regional scale)? (A+C+D) *Necessary*
- Has the traditional drive-hunt had an impact on the levels of genetic diversity within the hunted populations over time? (A+B+C) *Desirable*
- Are the species taken nowadays the same as historically? (A+B) *Desirable*
- Do the different villages that practise drive hunting of dolphins take the same species and/or hunt the same populations? (A+C) *Desirable*
- Does genetic monitoring reveal changes in the catch composition? Genetic sampling through time could indicate if there are such changes as well as changes in the levels of genetic diversity. (A+C) *Desirable*.



**INTERNATIONAL UNION FOR
CONSERVATION OF NATURE**

Rue Mauverney 28
1196 Gland
Switzerland
Tel +41 22 999 0000
Fay +41 22 999 0002
www.iucn.org/species

